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水稻碾米品質及米粒外貌之品種變異[1]

郭　益　全[2]

摘要：以引自日本及本省育成之稉稻與引自 IRRI 、本省傳統及本省育成之秈稻計59個水稻品種供試。在力求均一之栽培管理與收穫調製條件下，調查參試水稻品種之碾米品質及米粒外貌等二大類品質性狀共計10項，以探討水稻碾米品質及米粒外貌之品種間變異。就型間言，碾糙率、白米率、完整白米率、糙米容重量、糙米粒寬、粒米千粒重、白堊質米出現頻度及白質堊面積大小等8性狀之表現以稉稻較佳；秈稻則有較長之粒長與較大之長寬比。就稉稻言，引自日本諸品種之平均碾米率、白米率、完整白米率、糙米容重量、白堊質米出現頻度及白堊質面積大小等6性狀均較本省育成者爲優。顯示本省稉稻品種，在碾米品質及米粒外貌方面尙須繼續加以改良。秈稻方面，本省育成品種之完整米率，白堊質米出現頻度及白堊質面積大小等3性狀之表現均優於引自 IRRI 及本省傳統之品種，顯示本省秈稻育種在此3性狀之改良確有實績。

目前國內各試驗場所新選育出有希望水稻材料之品質檢定，係由臺中區農業改良場統籌辦理，其檢定項目係綜合美國農部及 IRRI 之方法，一般分成碾米品質、米粒外貌及烹調與食用品質等三大類。其中，碾米品質主要由碾糙率、白米率及完整白米率等三項因素來評估。米粒外貌則由精白米粒之大小、形狀、透明度及白堊質（包含心、腹及背白）之有無及多寡來決定。而烹調與食用品質之判定，往昔是以生米粒之膠化溫度、顆粒澱粉含量、膠體硬度及蛋白質含量來評定，近則進行米飯樣品之官能試食，以爲食用品質分級之依據。

稻米品質雖屬品種特性，但受栽培方式、栽培環境、肥料及水分管理、收穫處理、貯存環境及烹調方式與條件等外在因子之影響[12]。研究顯示，碾糙率、白米率及完整白米率等3個碾米品質性狀不僅有栽培地點間[6,8,9]、期作間[8,9]之差異存在，且期作與地點及品種與地點之交感亦顯著[9]，尤以完整米率爲然[4,9]。 Khush *et al.*[17] 認爲穀粒成熟期間外界之溫度、溼度及稻穀之收穫調製是影響完整米率之最重要的環境因子。完整米率之表現也與穀粒之大小(size)、粒型（shape）及外貌（appearance）有關，一般以粒長中等且米粒透明之水稻品種有較高之完整白米率。

米粒白堊質之多寡直接影響白米之外觀，間接影響完整白米率，是米粒外貌評價中一極重要之性狀。郭等[8]之數據顯示米粒之白堊質性狀有栽培地點間之差異存在，品種與栽培地點間之交感顯著；林[6]則報告期作間、品種間、期作與品種交感、栽培地點與品種交感及品種與期作與栽培地點交感極顯著。顯示米粒之白堊質性狀雖爲可遺傳之性狀，但可知或不可知之環境因子則能影響其表現。研究指出米粒白堊質之出現與稻株抽穗開花後外界之持續溫度有關，高溫或增加白堊質米粒出現之頻[16,18,20,25]或增加白堊質之面積[14,19]，抽穗後適量之追施氮肥亦可降低白堊質米之出現頻度[21]與面積[19]。冷害、雨害、旱害、風害及病蟲害等導致稔實受障礙時，腹白亦易出現[10,22]。而白堊質米出現之感受期則在開花後20—30天之穀粒充實盛期[22]。

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本省南北狹長，形如紡錘，中央山脈貫穿南北，各地農業環境殊有不同，而米質性狀受外界環境相當程度之影響已如上述，且目前國內有關品質性狀之數據，或來自國外[17]、或為分布各地諸試驗場所自選有希望材料品質檢定之累積[3,5,7]、或為單地點區域試驗材料檢定結果之綜合[3,5,7]、或為少數品種之檢定成績[1,2,11]，而曾被栽培或已命名推廣諸品種在同一栽培條件與齊一收穫調製等操作下，所檢得各品質性狀之數據則鮮有，為充實良質米遺傳育種之基礎資料乃進行本項試驗，本文僅報告碾米品質及米粒外貌之品種變異，至於烹調與食用品質之資料則另文提出。

材料與方法

以引自日本良質早熟稻越光等及本省各場所育成之臺農68號等稉稻與引自 IRRI 之 IR8 等、本省傳統秈稻大埔菊仔等及本省各場所育成臺中秈16號等秈稻共計59個水稻品種供試（如表1）。1984年1期作。逢機完全區集設計，4重複。每品種每重複插植5行，每行12株，行株距 25×25cm，單本植。肥料用量 N、P_2O_5 及 K_2O 依次為80、40 及 50kg/ha 栽培管理按一般方法行之。成熟後適期收穫每小區中間30株，日光乾燥至稻穀含水量13%左右，室溫貯藏1個月左右後，開始進行各項碾米品質及米粒外貌之測定。就中碾米品質之測定係參考 Webb *et al.*[23]、Webb[24]、Barber and Barber[13] 及 Khush *et al.*[17] 之方法進行。米粒白堊質面積大小（等級）之判定則按 Khush *et al.*[17] 及 Ikenhashi and Khush[15] 之標準判定，白堊質米粒出現頻度為各該樣品逢機1000粒完整白米中，白堊亞質米出現之頻度。糙米容積重則以日本木屋製作所製造之容積重測定器所取各該樣品糙米之量。

表1. 試 驗 材 料

Table 1. Materials used

Orgigin	Variety name
Japonica Varieties	
Japan Varieties	Hokuriku No 100, Torokiwasei, Toyonishiki, Koshihikari, Sasanishiki.
Taiwan Improved Varieties	Taipei No. 309, Taipei No. 311, Hsinchu No. 56, Hsinchu No. 57, Hsinchu No. 62, Hsinchu No. 64, Taichung No. 65, Taichung No. 178, Taichung No. 181, Taichung No. 187, Taichung No. 188, Taichung No. 189, Tainung Yu WF 5A, Tainung No. 61, Tainung No. 62, Tainung No. 67, Tainung No. 68, Tainan No. 3, Tainan No. 5. Tainan No. 5, Tainan No. 6, Chianan No. 8, Kaohsiung No. 1, Kaohsiung No. 137, Kaohsiung No. 139, Kaohsiung No. 140, Kaohsiung No. 141, Taitung No. 27, Taitung No. 28, Taitung No. 29.
Indica Varieties	
IRRI Varieties	IR 8, IR 20, IR 24, IR 26, IR 36, IR 38.
Traditional Varieties	Pao-yeh-chu, Ta-p'u-chu-tzu, Ai-chueh-nan-t'e, Hsia-yeh-ching No. 8, Chen-chu-ai No. 11. Hsinchu-ai-chueh-chien.
Taiwan Improved Varieties	Chianung Sen No. 6, Chianung Sen No. 8, Chianung Sen No. 11, Chianung Sen No. 12, Kaohsiung Sen No. 2, Kaohsiung Sen No. 7, Taichung Native No. 1, Taichung Sen No. 2, Taichung Sen No. 5, Taichung Sen No. 10, Taichung Sen No. 16.

結 果

59個秈稉稻品種之碾糙率、白米率及完整白米率等3個碾米品質主要評估性狀之測定結果示於表2

，由表可知稉型稻品種碾糙率之變域介於76.5%（臺南7號）至82.4%（轟早生）之間，平均80.0%；秈稻品種碾糙率之變域則介於73.8%（臺中秈16號）至79.2%（狹葉青8號）之間，平均76.1%。兩型品種碾糙率之變異範圍很相近，均在6%左右，但稉稻品種之平均碾糙率則極顯著地高於秈稻品種之平均碾糙率，就型內言，引自日本良質稉稻品種碾糙率之變異範圍在2%左右，下限品種爲笹錦（80.3%），上限品種爲轟早生（82.4%）；國內育成諸稉稻品種碾糙率之變異範圍在6%左右，下限品種是臺南7號（76.5%），上限品種則爲臺北311號與臺中188號（82.3%）。國內育成諸稉稻品種之平均碾糙率雖顯著地低於引自日本諸稉稻之平均碾糙率，但國內育成稉稻品種臺中188號與臺北311號兩品種碾糙率之表現與引自日本碾糙率表現最優之品種轟早生相比，却不遜色。此外，臺北309號、新竹56號、臺中65號、臺中181號、臺南5號、臺南6號、高雄141號及臺東28號等8個品種之碾糙率也與引自日本良質稉稻之平均碾糙率相近或較高。引自IRRI、傳統及本省育成等三類不同來源秈稻品種之平均碾糙率相當接近，以傳統秈稻品種之平均碾糙率最高，本省育成者次之，引自IRRI者最低。就中僅傳統品種與引自IRRI品種之平均碾糙率的差異達5%之顯著水準。引自IRRI、傳統及本省育成等三類不同來源秈稻品種碾糙率變域之上限品種依序爲IR-24號、狹葉青8號及高雄秈12號，而變域之下限品種三類來源依序爲IR-36號、大埔菊仔與臺中秈16號。諸秈稻品種中碾糙率與引自日本良質稉稻之平均碾糙率相近或較高者則不曾發現。

表2. 水稻碾米品質之品種變異

Table 2. Variability of milling quality of rice varieties

	Brown rice rate		Total milled rice rate		Head rice rate	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Japonica Varieties	A[1]80.0±1.69	76.5—82.4	A72.2±2.55	67.0—76.6	A49.7±6.24	39.2—61.5
Japan Varieties	a[2]81.4±0.78	80.3—82.4	a75.2±1.26	73.5—76.6	a54.9±4.12	50.5—61.5
Taiwan Improved Varieties	b79.8±1.69	76.5—82.3	b71.8±2.38	67.0—75.2	b48.9±6.16	39.2—58.7
Indica Varieties	B76.1±1.85	73.8—79.2	B68.2±2.69	62.9—73.4	A48.4±4.62	40.5—57.3
IRRI Varieties	b75.6±1.35	74.5—77.3	de67.9±1.46	66.0—69.4	cd46.3±2.08	43.4—48.0
Traditional Varieties	c77.3±1.33	75.4—79.2	cb70.0±1.93	68.1—73.4	bc47.7±4.97	40.5—52.8
Taiwan Improved Varieties	cd76.1±1.31	73.8—78.0	ce68.2±2.19	62.9—70.8	ab50.5±2.91	42.9—57.3

1 and 2: Means in each column with the same letter are not significantly dfferent at 1% level.

稉稻品種白米率變域之上限爲76.6%（轟早生），下限爲67.0%（臺農67號）。秈稻品種白米率變域之上限爲73.4%（狹葉青8號），下限爲62.9%（臺中秈16號），秈稉稻兩型品種白米率之變異範圍十分相近，均在10%左右，唯兩型品種之平均白米率則稉稻極顯著地高於秈稻（表2）。引自日本良質稉稻品種之平均白米率爲75.2%，變域爲73.5%（笹錦）至76.6%（轟早生）。

本省育成稉稻品種之平均白米率爲71.8%，變域爲67.0%(臺農61號)至75.2%(臺中188號）之間。顯著低於引自日本良質稉稻之平均白米率，且具有較大之變異範圍。而本省育成稉稻品種中，白米率之表現與引自日本良質稉稻品種平均白米率相近或稍低者（>74%），計有臺北309號、臺北311號

、臺中65號、臺中188號、臺中 189號、高雄選 1 號、高雄141號及臺東 28號等 8 個品種。引自 IRRI、傳統及本省育成等三類不同來源秈稻品種羣之平均白米率之差異不顯著，而以傳統品種者最高，本省育成者次之，引自 IRRI 者最低。IR8 號、大埔菊仔及臺中秈16號依序爲三類不同來源秈稻品種羣中白米率較低之品種，而白米率表現較優之品種三類型依序爲 IR24 號、狹葉青 8 號及嘉農秈 6 號。而本省育成秈稻品種中，嘉農秈 6 號、嘉農秈選 8 號、嘉農秈12號、高雄秈 2 號及臺中秈 5 號等 5 個品種之白米率達70%左右，與本省育成稉稻平均白米率71.8%相近。

稉稻品種之平均完整白米率爲49.7%，略高秈稻之48.4%，但兩型間之差異不顯著。但引自日本質稉稻之平均完整白米率則顯著地高於本省育成之稉稻及三類不同來源之秈稻(表 2)。秈稉兩型各來源品種羣完整白米率表現較佳之品種爲笹錦 (61.5%，引自日本之稉稻)、高雄141號 (58.7%，本省育成之稉稻)、IR38 號 (48.0%，引自 IRRI 之秈稻)、矮脚南特 (52.8%，傳統之秈稻) 及嘉農秈 6 號 (57.3%，本省育成之秈稻)。各來源完整米率表現較差之品種則依次爲越光 (50.5%)、臺中 178號 (39.2%)、 IR8 號 (43.4%)、狹葉青 8 號 (40.5%) 及臺中秈 2 號 (42.9%)。所有參試品種中，完整米率在58%以上 (接近或超過引自日本良質稉稻之平均完整白米率54.9%) 之本省育成之稉稻有臺北309號、臺北311號、新竹56號、臺中65號、臺中188號、臺中189號、臺農68號、高雄選 1 號、高雄 141號、臺東27號及臺東28號等11個品種，秈稻爲嘉農秈 6 號、臺中秈 5 號及臺中秈16號等 3 個品種。

表3. 水稻容重量與穀粒性狀之品種變異

Table 3. variability of Volume weight and grain dimensions of brown rice.

	Volume weight (g/0.1l)		Grain length (mm)		Grain width (mm)		Length/width	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Japonica Varieties	A[1]81.6±1.38	78.4−83.8	B4.61±0.20	4.22−5.06	A2.70±0.15	2.49−2.95	B1.70±0.11	1.53−1.91
Japan Varieties	a[2]82.9±0.59	82.3−83.5	c4.51±0.18	4.22−4.68	b2.62±0.03	2.60−2.66	c1.72±0.08	1.61−1.80
Taiwan Improved Varieties	b81.3±1.35	78.4−83.8	c4.64±0.18	4.34−5.06	a2.72±0.16	2.49−2.95	c1.70±0.11	1.53−1.91
Indica Varieties	B79.3±1.16	77.8−81.9	A5.46±0.69	4.66−6.60	B2.41±0.29	2.00−2.78	A2.36±0.56	1.64−3.27
IRRI Varieties	c79.3±1.89	77.8−81.9	a5.82±0.66	5.10−6.60	cd2.33±0.32	2.02−2.63	a2.56±0.63	1.94−3.27
Traditional Varieties	c79.6±0.89	78.4−80.8	b4.98±0.16	4.66−5.10	b2.61±0.10	2.49−2.72	b1.91±0.11	1.72−2.03
Taiwan Improved Varieties	c79.7±1.16	77.9−81.1	a5.51±0.78	4.76−6.48	c2.42±0.27	2.00−2.78	a2.39±0.50	1.64−3.07

1 and 2 : Means in each column with the same letter are not significantly different at 1% level.

稉稻容重量之變域在 78.4g/0.1l (臺農61號) 至 83.8g/0.1l (臺北309號) 之間，變異範圍爲，平均爲 81.6g/0.1l；秈稻容量重之變域在 77.8g/0.1l (IR38) 至 81.9g/0.1l (IR24) 之間，變異範圍爲 4g，平均爲 79.3g/0.1l。秈稉兩型容重量之變異範圍之差距甚小，但兩型平均容重量之差異則極顯著。就稉稻言。引自日本良質稉稻羣之平均容重量爲 82.9g/0.1l，變域爲 82.3g/0.1l (北陸100號) 至 83.5g/0.1l (轟早生)，本省育成稉稻之平均容重量爲 81.3g/0.1l，變域下限爲 78.4g/0.1l (臺農61號)，上限爲 83.8g/0.1l (臺北 309 號)。本省育成稉稻羣之平均容重量雖顯著地底於引自日本之良質稉稻羣，但容重超量超過 82g/0.1l 者，計有臺北309號、臺北311號、

新竹56號、新竹57號、臺中65號、臺中187號、臺中188號、臺中 189號、臺農68號及高雄選1號等10個品種，其中臺北309號與臺中187號之容重量更高達 83.0g/0.11 以上，與引自日本良質粳稻羣中容重量上限品種轟早生者難分軒輊。引自 IRRI 傳統與本省育成等三類不同來源秈稻羣之平均容重量，三類羣間差異不顯著，唯達容重量 80g/0.11 以上之本省育成秈稻羣中有嘉農秈6號、嘉農秈11號、臺中在來1號及臺中秈5號等4個品種。

表3糙米粒長、粒寬、長寬比等數據顯示供試粳稻及傳統秈稻概屬粒形短圓之品種，引自 IRRI 及本省育成（臺中在來1號及臺中秈2號除外）之秈稻品種概爲粒形細長之中長粒品種。供試品種中以引自日本良質粳稻羣之平均糙米粒長最短，引自 IRRI 粒稻羣之平均糙米粒長最長。本省育成秈稻羣粒長之變異範圍最大，由早期品種之短米粒至晚近品種之長穀粒的變化，似與晚近咸認長粒秈稻甚高產之觀念有關。平均糙米粒寬以本省育成粳稻羣者最寬，以引自 IRRI 秈稻羣者最小，引自日本粳稻羣糙米粒寬之變異範圍最小，僅約 0.06mm 。引自日本與本省育成兩類粳稻間平均長寬比差異不顯著，引自 IRRI 與本省育成秈稻羣間之差異亦不顯著。

白米1000粒重方面，粳稻品種之平均爲 19.2g，變域介 16.6g（北陸100號）至 21.8g（臺中188號）之間，變異範圍約 5g 左右。秈稻品種之平均1000粒重爲 18.3g，變域爲 16.9g（臺中秈5號）至 21.0g（IR24號），變異範圍爲 4g；秈粳兩型1000粒重之變異範圍相近，而兩型品種平均1000粒重之差異雖不大（約 1g 左右），但達5％之顯著水準。就型內言，本省育成粳稻品種之平均1000粒重顯著地重於引自日本之良質粳稻羣之平均，而引自 IRRI、傳統及本省育成等三類不同來源秈稻羣之平均1000粒重則無顯著差異存在（表4）。

表4. 水稻1000粒重與白堊質性狀之品種變異

Table 4. Variability of 1000-grain weight and chalkiness characters of milled rice.

	1000-grain weight(g)		The occurrence frequency of chalky endosperm		The opaque area of chalky endosperm	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Japonica Varieties	A[1]19.2±1.20	16.6–21.8	B20.2±12.76	3.6–53.9	B2.6±0.50	1.8–3.5
Japan Varieites	b[2]17.7±1.02	16.6–18.7	d12.4±5.26	6.9–19.3	d2.2±0.22	1.9–2.4
Taiwan Improved Variaties	a19.4±1.05	16.9–21.8	e21.8±12.81	3.6–53.9	e2.7±0.50	1.8–3.5
Indica Varieties	A[3]18.3±1.68	16.9–21.0	A60.9±33.34	5.8–94.7	A4.8±1.67	2.6–7.7
IRRI Varieties	a18.3±1.85	17.2–20.1	a78.6±24.71	41.6–92.2	a5.5±1.45	3.8–7.3
Traditional Varieties	a18.3±0.85	17.0–19.7	a75.6±20.88	38.0–94.7	a5.7±1.74	4.3–8.3
Taiwan Improved Varieties	a18.5±1.27	16.9–20.7	b48.7±34.29	5.8–94.7	b4.3±1.49	2.6--7.7

1 and 2 : Means in each column with the same letter are not significantly different at 1% level.

3 : Difference of 1,000-grain weight between *japanica* and *indica* types is significant at 5 % level.

粳稻羣白堊質米粒出現頻度之變域介於3.6%（高雄選1號）至 53.9%（新竹64號）之間，變異範圍爲50%，平均爲20.2%。秈稻羣白堊質米粒出現頻度之變域爲5.8%（臺中秈16號）至 94.7%（

高雄秈 2 號），變異範圍爲89%，平均爲60.9%，均較稉稻品種爲高（表 4）。就稉稻言，引自日本良質稉稻羣白堊質米出現頻度之平均爲12.4%，變域上限爲19.3%（笹錦），下限是6.9%（豐錦）；本省育成稉稻品種之平均白堊質米粒出現頻度爲 21.8%，變域上限是 53.9%（新竹64號），下限爲3.6%（高雄選 1 號）。兩類相比，引自日本良質稉稻之白堊質米出現頻度的變異範圍與平均白堊質出現頻度均顯著地低於本省育成稉稻羣之表現。但國內育成稉稻稻品種高雄選 1 號與高雄 141號兩品種白堊質米出現頻度之表現與引自日本稉稻羣中白堊質米出現頻度最小的品種豐錦相比，並不遜色；同時臺北309號、臺中65號、臺中178號、臺中 189號、臺農68號、臺南 6 號、臺南 7 號、嘉南 8 號等 8 個品種白堊質米粒出現頻度均在12%以下，而與引自日本良質稉稻羣之平均相近或更少，此顯示本省育成稉稻羣中亦有若干品種本性狀之表現是相當不錯的。秈稻方面，本省育成秈稻羣之平均白堊質米粒出現頻度遠低於引自 IRRI 及傳統秈稻之平均，且本性狀表現之平均雖顯著地劣於稉稻，但仍有臺中秈16號（5.8%）、臺中秈 10號（13.5%）及嘉農秈 6 號（14.3%）等三個品種之表現與引自日本良質稉稻之平均相近或較低，臺中秈 5 號之白堊質米粒頻度（24.2%）亦有與本省育成稉稻之平均相近。

米粒白堊質等級（面積大小）方面，秈、稉兩型水稻之型間與型內變異與白堊質米粒出現頻度之變異類似。稉稻羣米粒白堊質等級變異之上限爲3.5（高雄137號），下限爲 1.8（高雄選 1 號），變異範圍1.7，平均2.6。秈稻羣米粒白堊質等級變異之上限爲7.7（高雄秈 2 號），下限爲2.6（臺中秈10號），平均 4.8。秈稻羣不僅米粒白堊質等級之變異範圍較秈稻羣者爲小，而且平均米粒白堊質等級亦極顯著低於秈稻羣者（表 4）。就型內言，引自日本稉稻羣之平均白堊質等級遠低於本省育成稉稻羣之平均，本省育成之秈稻羣的平均白堊質等級亦顯著地低於引自 IRRI 及傳統秈稻羣之平均。而本省育成之稉稻品種中有臺北309號、臺中178號、臺中188號、臺中189號、高雄選 1 號、高雄 141號及臺東28號等 7 個品種本性狀之表現優於或接近引自日本良質稉稻羣之平均，本省育成秈稻羣中亦有嘉農秈11號、臺中秈10號及臺中秈16號等 3 個品種本性狀之表現與本省育成稉稻羣之平均相近。

討 論

稻米之產銷大致可區分成三個層面，一爲生產者，二爲加工販賣者，三是消費者。目前本省已有確立完整之稻米分級收購與銷售制度之芻議，但尚未完成。因之，農民以純收益考慮，仍以栽培抗病蟲害之豐產品種爲主，而較不重視米質之良窳。加工販賣者在商言商，希望購入之稻穀能碾出較多量之糙米（即高碾糙率），且糙米碾成白米後也能有較高之白米率及完整白米率，碾得之白米更希望粒形整齊透明亮麗（優良之米粒外貌），煮成之米飯香噴可口（食用品質良佳），以爭取顧客，佔有市場。消費者則希望購入之白米粒粒瑩澈，個個完美且味香適口（僅注重米粒外貌及食用品質）。亦即由於稻米產銷層面之不同，對關係複合性狀稻米品質性狀之要求也隨之有別。唯對育種家而言，碾米品質、米粒外貌及烹調與食用品質等三類品質性狀均須面面俱到，通盤考慮。由於糧政決策之關係，稻作工作者過去之努力概僅注重稻穀產量之提高，較忽視稻米品質之改良。而今時推世移，高品質水稻之育成乃成當前水稻工作者刻不容緩之任務之一。因之，在同一栽培條件與齊一收獲調製等操作下，全面檢討本省若干主要秈稉品種稻米品質之表現，一則可用爲將來遺傳工作之基礎數據，二則可檢討在過去豐產爲導向之育種目標下，主要命名推廣品種米質性狀之優劣，是爲本研究之最主要目的。經以引自日本之良質稉稻羣爲對照檢討發現，就集團之平均表現加以比較時，本省育成之稉稻及秈稻碾米品質及米粒外貌之表現尚不如引自日本之良質稉稻，唯就個別品種言，若干本省育成稉稻品種及少數秈稻品種部份主要品質性狀如完整白米率及米粒白堊質性狀之表現，與引自日本良質稉稻者相比並不遜色，同時本省育成秈稻品種之平均完整白米率及白堊質性狀均較傳統秈稻品種之平均爲優。顯示稉稻育種方面，已適合本省之栽培環境，產量尚具水準，且碾米品質及米粒外貌俱優之種源已不虞缺乏；而本省育成多數秈稻品種在完整白米率及米粒白堊質性狀方面之改良亦頗具實績。

由於國內消費者對粒形及米粒大小之選擇並不苛刻，故就國內市場言，市場品質（碾米品質與米粒外貌之合稱）之好壞取決於碾糙率、白米率、完整白米率及米粒白堊質性狀，而因爲白堊質米粒出現頻度與米粒白堊質面積等兩項米粒白堊質性狀不僅直接影響米粒外觀，且間接影響完整白米率（白堊質多之米粒於碾白時較易碎裂），爲較主要之市場品質性狀。本研究中雖發現本省育成稉稻羣諸主要市場品質性狀之平均皆不如引自日本良質稉稻羣，但在白堊質米粒出現頻度性狀方面，已發現高雄選1號及高雄141號等2個品種之表現與引自日本本性狀表現最優之品種豐錦相當；臺北309號、臺中65號、臺中178號、臺中189號、臺農68號、臺南6號、臺南7號及嘉南8號等8個本省育成稉稻品種白堊質米粒出現頻度在12%以下，而與引自日本良質稉稻羣之平均相似。米粒白堊質面積大小性狀方面亦發現有臺北309號、臺中178號、臺中188號、臺中 189號、高雄選1號、高雄141號及臺東28號等7個本省育成稉稻品種之表現小於（優於）或接近引自日本良質稉稻羣之平均；臺北309號、臺北311號、新竹56號、臺中65號、臺中188號、臺中189號、臺農68號、高雄選1號、高雄141、臺東 27號及臺東28號等11個品種完整白米率之表現在53%以上，而接近或超過引自日本良質稉稻羣之平均完整白米率（54.9%）；白米率方面則有臺北309號、臺北311號、臺中65號、臺中188號、臺中189號、高雄選1號、高雄141號及臺東 28號等8個品種與引自日本良質稉稻羣之平均白米率相近；碾糙率方面亦有臺北309、臺北311號、新竹56號、臺中65號、臺中181號、臺中189號，臺南5號、臺南6號、高雄141號及臺東28號等 10個品種與引自日本良質稉稻羣之平均碾糙率相近或較優。檢討這些市場品質表現優異的本省育成之稉稻品種發現，除臺中189號、臺南7號及臺農 68號等3個品種係在良質米品種漸被重視之晚近被命名推者廣外，餘均屬較早期以豐產爲導向時育成之稉稻品種，可確定市場品質表現優良新品種之選獲並不困難。

又，高雄141號品種於民國 69年登記命名，各項市場品質性狀表現皆在水準以上，目前栽培面積僅次於臺農67號與新竹64號，居全省第三位。但因有脫粒較難而易帶有枝梗，去殼工作較麻煩，易穗上發芽及不耐儲藏等缺點，故雖具有良好之市場品質及食味尚佳（小規模試食成績，大規模試食尚在進行中）等優點，將來是否能與日本良質米品種越光一樣，於重視良質米之條件下更受注意及栽培，仍有待考驗。

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Variability of Milling Quality and Grain Appearance of Rice Varieties[1]

Yih-chuan Kuo[2]

Summary

This study was intended to provide some basic imformatiom on the variability of milling quality and grain appearance of rice varieties. A total of 10 grain quality characters relating to milling quality and grain appearance were evaluated, under uniform field practices and postharvest handling operations, for 59 rice varieties including *japonica* (Japan and Taiwan improved varieties) and *indica* (IRRI, Traditional, and Taiwan improved varieties) types. In general, the mean performance of some characters of *japonica* type such as brown rice rate, total milled rice rate, head rice rate, brown rice volume weight (0.11), brown rice grain width, brown rice 1,000-grain weight, the occrruence frequency of chalky endosperm and the opaque area of chalky endosperm were better than those of *indica* type. On the other hand, *indica* type was characterized by longer grain length and larger length/width ratio. Among *japonica* rice varieites, the mean values of brown rice rate, total milled rice rate, head rice rate, brown rice volume weight, the occurrence frequency of chalky endosperm and the opaque area of chalky endosperm of Japan varieties were better than those of Taiwan improved variaties. Among *indica* rice varieties, the mean performance of head rice rate, the occurrence frequency of chalky endosperm and the opaque area of chalky endosperm of Taiwan improved varieties were better than those of IRRI or Traditional varieties.

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不同形式及濃度鐵源對水稻花藥培養之影響[1]

陳駿季　許家言　蔡新聲[2]

摘要：將水稻花藥培養於含不同形式及濃度鐵源的培養基，探討對水稻花藥癒合組織形成及分化能力的影響，及瞭解葉綠素含量與鐵源濃度及移植成活率的關係。試驗結果顯示添加 0.1mM 之 $Na_2FeEDTA$（二價鐵）或 NaFeEDTA（三價鐵）於誘導癒合組織的培養基，有助於花藥癒合組織的形成，但提高濃度至 0.2mM，反而產生毒害。

癒合組織於含 0.05mM $Na_2FeEDTA$ 或 0.1mM NaFeEDTA 或 0.05mM $Na_2FeEDTA$ 混合0.05mM NaFeEDTA之培養基形成後，移至含相同鐵源之分化培養基，能分化較多的綠株；提高$Na_2FeEDTA$ 的濃度至0.1mM或0.2mM 時，綠株分化率顯著降低。NaFeEDTA 在受測的三種濃度中，對綠株分化影響不大。在本試驗受測的濃度與形式範圍內，白苗的分化，不受鐵源影響。

分化綠株葉片之葉綠素含量與培養基內鐵源的形式及濃度有很大的關係，此種關係受到植株根系大小影響。約有85%之分化綠株，移植前具有發育中等之根系，其植株葉綠素含量與培養基內鐵源濃度呈正相關，同時葉綠素含量高的植株，具有較高的移植成活率。

利用組織培養誘導植物體形成的過程中，經常可以發現一些喪失葉綠素合成機能的白苗個體(6,26,27)，這種白苗個體產生的頻度，與不同品種及培養方式有很大的關係(7,1)。一般經由癒合組織所分化的植株較易形成白苗，而經由生長點或胚狀體所產生的植株，形成白苗的機會很少。以水稻而言，經由花藥培養所分化的植株中，白苗所占的比例相當大，一般品種介於10～20%之間，雜交種後代則更高，其程度依品種不同而異，同時改變培養環境亦能使白苗的比例改變(6,7,27)。

除了白苗的產生之外，水稻花藥培養所分化的綠株中，常可見到一些黃綠色的植株，這些植株雖可合成葉綠素，但其能力顯然不足，往往是造成移植初期即死亡的原因之一。因此如何減少白苗的產生及提高綠苗葉綠素合成的能力，是目前從事花藥培養急欲解決的問題。

鐵在組織培養誘導植物體形成的過程中扮演著極重要的角色，同時也是合成葉綠素過程中不可缺的主要微量元素之一(13,20,25)。許多報告已指出鐵源的形式與濃度對植株葉綠素含量影響很大(9,13)，但這方面之研究大部分在 in vivo 狀況下進行，in vitro 的狀況進行研究的報告相當少，更缺乏有關水稻的資料。本試驗目的乃探討不同形式及濃度的鐵源對水稻花藥培養癒合組織及綠苗形成能力的影響，同時瞭解鐵源濃度對綠株之葉綠素含量及移植成活率的影響，希望藉此提高花藥培養之育種效率。

材料及方法

試驗用之水稻品種爲粳稻臺農67號，花藥的選取、消毒及接種皆按本研究室以往所行的方法(1,2)。

1.臺灣省農業試驗所　研究報告第1284號。本研究承行政院農業委員會經費補助（75農建一2.2糧一129），文承成功大學生物系黃定鼎副教授斧正，特此申謝。

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誘導癒合組織的培養基，除鐵源外，其餘成份依據陳等[2] 所使用的配方；而誘導植株分化的培養基，除鐵源外，其餘成份則依據 Chen[7] 所使用的配方。七種不同濃度或形式的鐵源分別爲 Na_2-FeEDTA (0.05 mM, 0.1 mM, 0.2 mM), Na_2FeEDTA 0.05 mM+NaFeEDTA 0.05 mM及 NaFeEDTA (0.05 mM, 0.1 mM, 0.2 mM)，其中 Na_2FeEDTA 乃根據 Dalton 等[9] 所述之方法由相同濃度之 $Na_2EDTA \cdot 2H_2O$ 及 $FeSO_4 \cdot 7\ H_2O$ 混合而成，是屬二價鐵之錯化合物，而 NaFeEDTA 屬三價鐵之錯化合物。

含單核期之水稻花藥接種於癒合組織誘導培養基，當癒合組織形成後再分別移至含相同成分鐵源的分化培養基，以避免不同鐵源之相互影響。

植株自分化培養基形成後，調查所分化之綠苗及白苗，綠苗並移至相同成分之 MS 培養基，置於 2,000 lux 光照下二星期，移植前根據根系大小、重量，將分化株分爲三羣，依Arnon[4] 所述之方法測定植株之葉綠素含量，而後將根系中等之綠株 (約占總分化株之85%) 移植於戶外，二星期後調查其移植成活率。

結　果

不同形式及不同濃度之鐵源對水稻花藥形成癒合組織能力的影響列於表 1 。結果顯示，不論培養基內所添加鐵源爲二價鐵或三價鐵，均以 0.1mM 濃度對癒合組織誘導的效果最好，鐵源濃度提高一

表 1. 鐵源對水稻花藥培養癒合組織形成之影響

Table 1. The effect of iron on callus formation in rice anther culture.

source of iron[1]	Conc. -mM-	No. of anthers cultured	% of anthers forming callus[2]
Fe (II)	0.05	171	39.18[ab]
Fe (II)	0.10	211	43.13[a]
Fe (II)	0.20	208	34.13[b]
{ Fe (II) Fe (III)	0.05 0.05	201	37.81[b]
Fe (III)	0.05	219	39.73[ab]
Fe (III)	0.10	170	48.82[a]
Fe (III)	0.20	203	33.99[b]

1. Fe(II): Na_2FeEDTA, Fe(III):NaFeEDTA
2. Means in each vertical column followed by the same letter are not significantly different at 5% level using Duncan's Multiple Range Test.

倍至 0.2 mM時，對癒合組織的誘導則有抑制的情形，顯示提高鐵源濃度對花藥已產生毒害作用。在相同鐵源濃度下，三價鐵源對癒合組織之誘導效果比二價鐵源好，但差異均未達顯著水準。就本試驗所用的鐵源形式及濃度中，以培養基內添加 0.1 mM Na_2FeEDTA 或 0.1 mM NaFeEDTA，較有利於花藥形成癒合組織。

表 2 爲不同形式及濃度之鐵源對癒合組織分化成綠苗及白苗的影響。二價鐵源與三價鐵源表現不盡相同，當分化培養基含二價鐵時，0.1mM濃度的鐵源組合之分化綠苗百分率爲20.33%，濃度降至 0.05mM時，對綠苗分化有明顯促進效果，可達33.20%，而提高濃度至 0.2mM時，雖略能提高綠苗

照[87]的影響，但往往適合綠化的條件都不適合分化。由本試驗得知，鐵源無法抑制白苗的產生，却能影響綠苗分化率及綠株之葉綠素含量，在各培養階段，適當的改變鐵源形式及濃度，以提高癒合組織形成能力及綠苗／白苗之比值，同時提高葉片中葉綠素含量以提高移植存活率，未嘗不是一種提高花藥培養育種效率的新手段。

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Effect of Iron on Rice Anther Culture[1]

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Summary

Experiments were conducted to identify iron requirement in rice anther culture for callus induction, plant regeneration, chlorophyll content of anther-derived green plants and its survival ability. It was found that rice anther cultured on a callus-inducing medium containing 0.1mM $Na_2FeEDTA$ or 0.1mM NaFeEDTA gave better result for callus formation. Increasing the iron concentration to 0.2mM showed toxicity.

Transferring pollen-derived callus on a regeneration medium containing 0.05mM $Na_2FeEDTA$ or 0.1mM NaFeEDTA or 0.05mM $Na_2FeEDTA$ plus 0.05 mM NaFeEDTA showed better green plant production. Less green plant production was observed when $Na_2FeEDTA$ concentration was increased to either 0.1mM or 0.2mM. Whereas, there was no difference on green plant production among 3 levels of NaFeEDTA tested. Regeneration ability of albino plants was not influenced by different sources or concentrations of iron tested in this study.

A close relationship between chlorophyll content of green plants and iron concentrations in root ing medium was observed. This phenomenon was related to root mass of green plants. About 85% of regenerated green plants had medium root weight (20-30 mg/plant). Their chlorophyll contents correlated positively with iron concentrations in rooting medium. Higher iron concentrations in the rooting medium also enhanced the survival rate of green plants upon transplanting.

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玉米不同粒型種源間子粒 zein 蛋白含量、粒重及產量差異之研究[1]

莊周瑞[2]　盧英權[2]　呂宗佳[3]

摘要：以四個馬齒種（dent）及四個硬粒種（flint）玉米自交系與其28個 F_1 組合為材料，於民國73年春作進行田間試驗，探討玉米子粒乾物與 zein 蛋白累積之關係，結果顯示：子粒乾物及 zein 蛋白累積之二次迴歸曲線，圖形極為一致，且均受直線生長速率及有效充實期之影響。

玉米自交系與 F_1 雜種間子粒乾重之差異，主要受充實期長短之影響；而 zein 蛋白累積量之差異，則共同受直線生長速率及有效充實期之影響。在不同粒型組合之 F_1 雜交種間，粒重及 zein 蛋白含量之差異則主要受直線生長速率之影響。相關分析亦顯示：粒重與 zein 蛋白含量有極顯著之正相關，而子粒產量亦與粒重及 zein 蛋白含量呈極顯著正相關；粒重及 zein 蛋白含量又分別與其本身之直線生長速率呈極顯著及顯著正相關。上述結果顯示，在本省春作栽培環境下，玉米子粒產量應以直線生長速率較快之品種較為有利。

粒型組合間，就各性狀之平均值及雜種優勢之表現比較，結果發現，大多數均以異粒型組合（硬粒種×馬齒種）較同粒型組合（硬粒種×硬粒種或馬齒種×馬齒種）為優異；而同粒型組合中，又多以硬粒種組合較馬齒種組合為優異。硬粒種與馬齒種間存在之優異雜種優勢現象，可為高產玉米親本組合模式之參考，而硬粒種較馬齒種表現優越之事實，亦足以顯示，於雜交種子採種時，宜以硬粒種組合或自交系為母本，較為有利。

玉米（*Zea mays* L.）為典型之異交作物，具有雜種優勢之現象。玉米品種改良主要亦以雜種優勢之利用，來使產量增加。本省過去玉米育種工作，由於受到以水稻為主的耕作制度之限制，為選育適合裡作栽培之品種，必需強調早熟性，因此所使用之育種材料大多為來自美國玉米帶的早熟自交系以及菲律賓等地的抗露菌病（downy mildew）系統，造成了使用種源之狹隘化，無法充分利用雜種優勢之特性[1]。近年來，由於稻米生產過剩，政府極力推行稻田轉作，因此晚熟而高產的玉米品種，在本省首次有了適宜的生長環境可資發展。

玉米雜種優勢主要表現於粒重及粒數上，二者均為玉米子粒產量之構成要素[6,21,22,27]。Tsai 氏等[23,24,25]認為玉米子粒中 zein 蛋白除了是主要的氮素積儲（N-sink）外，亦控制著子粒乾物質之累積，因此，對粒重及子粒產量之形成有直接之影響。

玉米子粒之充實，除受供源（source）及積儲（sink）強度之影響外，二部位間物質之轉運（translocation）亦佔有重要之地位。影響物質轉運之因素，就子粒的乾物質累積之生理因素（physiological components）而言，以子粒充實速率（grain filling rate）及有效充實期（effective filling period duration）之影響最為重要[4,8,16]。

本試驗之目的，即在以影響粒重的有關性狀為探討對象，利用馬齒種及硬粒種二種種源之自交系

1.臺灣省農業試驗所研究報告第1285號。本文為第一作者碩士論文之一部份。承蒙劉博士清協助資料之分析，謹致謝忱。
2.依序為本所前農藝系助理，國立中興大學糧作所碩士班畢業生、國立中興大學農藝系教授。臺灣省　臺中市。
3.本所農藝系研究員。臺灣省　臺中縣　霧峰鄉。

為材料，進行彼此間之全互交，以探討粒型組合間，雜種優勢表現之差異，及造成此種差異之可能原因，藉以尋求最佳雜種優勢組合模式，作爲今後選育高產玉米品種之參考。

材料與方法

一、材料

本試驗以四個溫帶馬齒種及四個熱帶硬粒種，共計八個自交系（如表一）及其全互交28個F_1組合（不含反交）爲材料，於民國73年春作，在臺灣省農業試驗所試驗農場進行試驗。

表 1. 自交系之代號與粒型

Table 1. Kernel forms of inbred lines.

Code	Inbred	Kernel type
A	Hi 25	dent
B	Oh545	dent
C	UH 1	dent
D	Pi 77—4257	dent
E	ICAL 210	flint
F	Hi 28	flint
G	CM 103	flint
H	CM 109	flint

二、方法

(一) 田間設計

採逢機完全區集設計，四重複。小區行長 5m，行株距80×25cm，三行區。每公頃種植50,000株。三要素肥料施用量爲 N：P_2O_5：K_2O＝200：90：60公斤／公頃。氮素60公斤及磷、鉀肥全量於基肥時一次施用；另於播種後一個月及雄花抽穗前，分別施用追肥及穗肥，每公頃氮素用量各70公斤。

(二) 調查方法

以每小區三行中之一行爲取樣區，餘二行用以估算產量，取樣行於雌穗吐絲前先予套袋，吐絲整齊後，同時除去套袋，使同時受粉。至受粉後10天、24天、28天、32天、36天及成熟期各取樣一次。每次取樣三穗，切取穗中央約 5 公分長度之部位，脫粒混合後，逢機取出100粒，經冷凍乾燥36小時後，取出秤取百粒重，並做爲 zein 蛋白含量測定之用。

(三) Zein 蛋白含量之測定方法

依 Dalby[3] 及 Jones 氏等[11] 之改良方法行之。

(四) 資料分析

1.調查性狀

(1) 粒重（KW）：單顆子粒之乾重（mg/kernel）。

(2) Zein 蛋白含量（Zein）：單顆子粒之 zein 蛋白含量（mg/kernel）。

(3) 子粒產量（Yield）：單株之子粒產量（g/plant）。

(4) 子粒之直線生長速率（KW. LGR）：自受粉後24天至32天間，子粒乾重之每日平均生長量(mg/day/kernel)。即：
KW. LGR＝〔KW(32DAP)－KW(24DAP)〕/8。

（5）Zein 蛋白之直線累積速率（Zein. LGR）：自受粉後24天至32天間，子粒 zein 蛋白之每日平均累積量（mg/day/kernel）。即：
Zein. LGR＝〔Zein(32DAP)－Zein(24DAP)〕/8

（6）子粒的有效充實期（KW. EFPD）：成熟期粒重與子粒直線生長速率之比值（days）。即：
KW. EFPD＝KW/KW. LGR

（7）Zein 蛋白的有效充實期（Zein. EFPD）：成熟期子粒中 zein 蛋白含量與其直線累積速率之比值（days）。即：
Zein. EFPD＝Zein/Zein. LGR

2.粒重及 zein 蛋白累積曲線之比較

粒重及 zein 蛋白累積曲線均以受粉後24、28、32、36天及成熟期五次取樣之資料，以二次迴歸曲線配合，求其直線迴歸係數（b_l）及二次迴歸係數（b_q），並以此迴歸曲線估算粒重及 zein 蛋白之最大累積值（max. $\hat{Y}$），及其出現時期（X）。

3.各性狀間之相關分析

進行七個性狀間之表現型相關分析。

4.不同粒型組合間各性狀之比較

為明瞭不同粒型組合間，各性狀表現之差異，將分屬二種不同粒型之自交系（表1），進行全互交所得28個 F_1 組合，區分為同粒型組合，即硬粒種與硬粒種或馬齒種與馬齒種間之雜交組合（各含6個組合）；及異粒型組合，即硬粒種及馬齒種間之雜交組合（含16個組合）。以比較不同粒型組合間各性狀之平均值及雜種優勢表現之差異。

5.雜種優勢

雜種優勢以 F_1 雜交種優於兩親平均值（mid parent；MP）之百分比估算之。即：
Heterosis(%)＝〔(F_1－MP)/MP〕×100

結　　果

一、粒重及 zein 蛋白累積曲線之比較

以受粉後24、28、32、36天及成熟期之粒重及 zein 蛋白之累積量，配合二次迴歸曲線 $\hat{Y}=a+b_lX-b_qX^2$，分別進行基因型平均，自交系與雜交種；及不同粒型組合間之粒重及 zein 蛋白累積情形之比較，結果示如表2及圖1之 a、b、c 及 d。

（一）基因型平均粒重與 zein 蛋白之比較（圖1之 a）：

粒重及zein蛋白累積之迴歸曲線，從受粉後第12天起，型態頗為類似，惟最大粒重（256.5mg/kernel）之累積期出現在受粉後第46.6天（表2），最大zein蛋白累積量（7.8mg/kernel）則出現在受粉後第40.4天，二者約有6天之差距。

（二）自交系與雜交種之比較（圖1之 b）：

對粒重之累積而言，自交系與雜交種 F_1 間之 b_l 值（24.71vs. 24.59mg/kernel/day）差異不大，b_q 值則以自交系之－0.283較雜交種之－0.259mg/kernel/day，降幅為大，致影響兩者最終之粒重差異加大，即最高累積量雜交種為265.2mg/kernel，大於自交系之228.5mg/kernel。最高累積量出現時期亦以雜交種之47.5天較自交系43.7天為長。就 zein 蛋白之累積而言，b_l 值（mg/kernel/day）以雜交種之1.47大於自交系之1.14，b_q 值則同為－0.018。而 zein 蛋白之最高累積量及其出現時期均以雜交種較自交系為

大且長，分別爲 8.0與 7.3 (mg/kernel) 及第 40.6與39.7 (天) 。顯示雜交種之粒重與 zein 蛋白之累積速率較自交系爲大且累積時期較長。

(三) F_1 組合之同粒型與異粒型間之比較 (圖 1 之 c及d) ：就粒重而言，b_1 值、b_q 值及最高累積量均以異粒型組合 (F×D) 較同粒型組合 〔F×F, D×D 或 (FF+DD/2)〕 爲大，惟

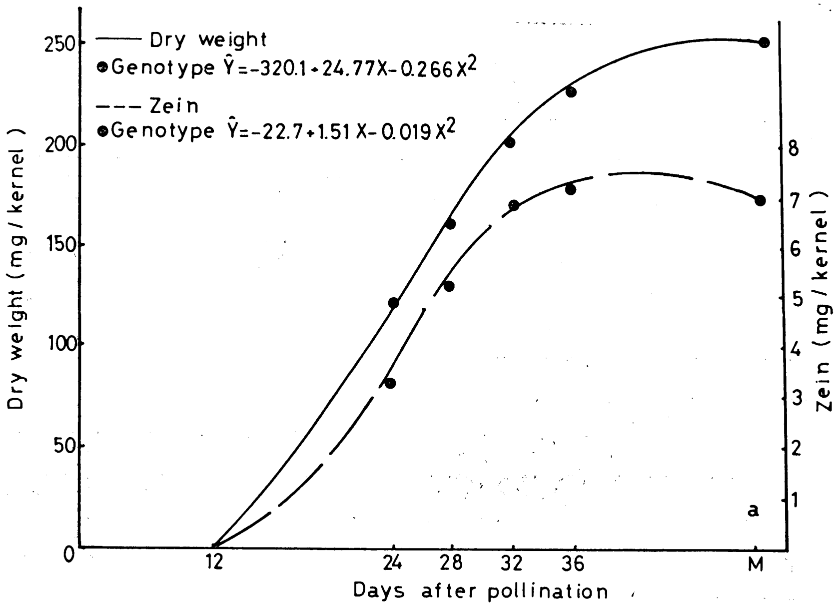

圖 1. (a)

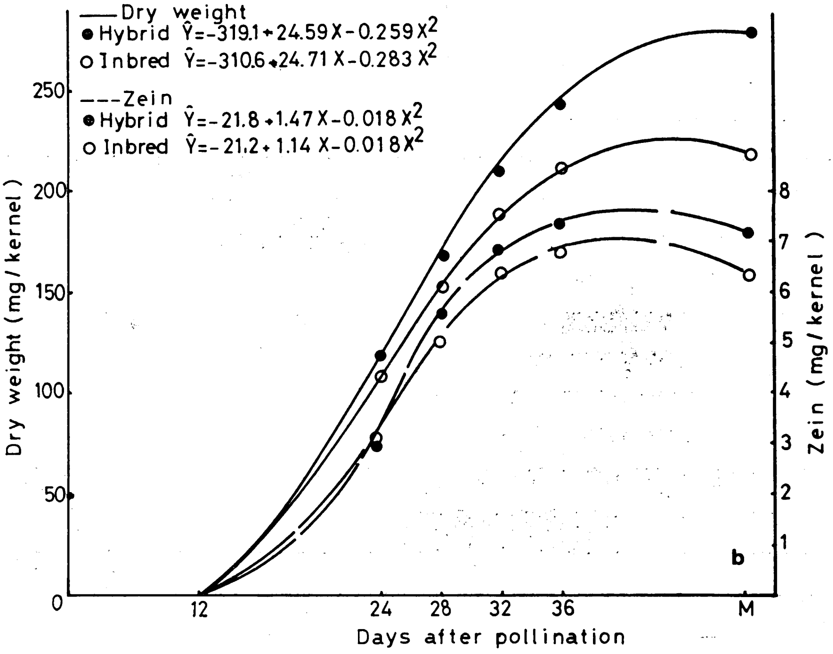

圖 1. (b)

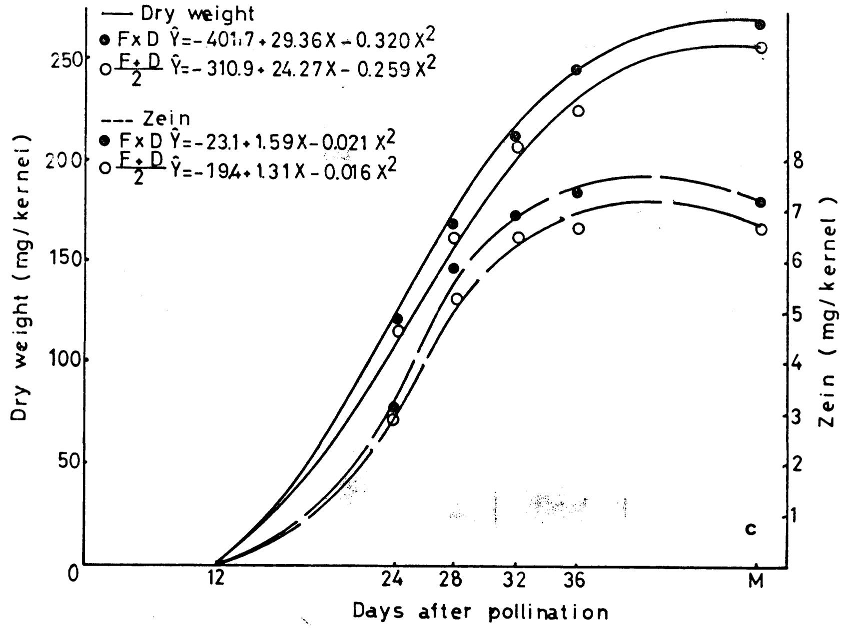

圖 1. (c)

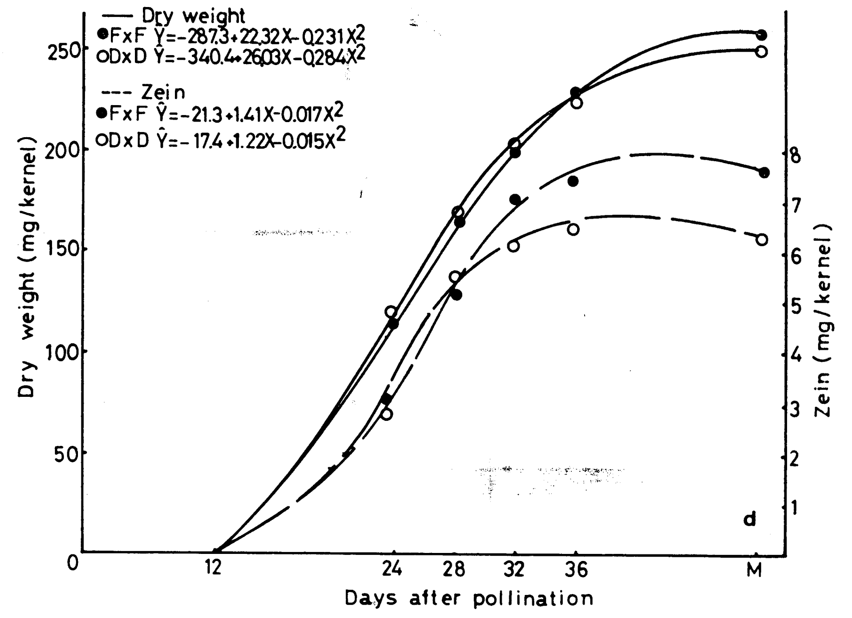

圖 1. (d)

圖 1. (a) (b) (c) (d) 子粒乾重及 zein 蛋白之累積曲線

Figure 1. Accumulation curves for dry weight and zein in maize kernels

最高累積量出現時期則以同粒型組合的 F×F 之 48.3天較異粒型組合之 45.9天爲長，而同粒型組合的 D×D 則同於異粒型組合（45.8及45.9天）。zein 蛋白之累積情形與粒重之趨勢相同。

表 2. 玉米自交系及雜種組合之粒重及 zein 蛋白累積迴歸曲線之截距（a），直線迴歸係數（b_l），二次迴歸係數（b_q）及其估計之最高累積量（max. $\hat{Y}$）和最高累積量出現時期（X）

Table 2. Coefficients of regression lines fitted for kernel dry weight and zein accumulations and predicted time (X) for giving maximum weight in inbreds and hybrid combinations.

Character	Source	a	b_l	b_q	max. $\hat{Y}$	X (giving max. $\hat{Y}$)
	Genotype	− 320.1	24.77	− 0.266	256.5	46.6
	Inbred	− 310.6	24.71	− 0.283	228.5	43.7
	Hybrid	− 319.1	24.59	− 0.259	265.2	47.5
Dry weight	F×F	− 278,3	22.32	− 0.231	260.8	48.3
	D×D	− 340.4	26.03	− 0.284	255.9	45.8
	(FF+DD)/2	− 310.9	24.27	− 0.259	257.7	46.8
	F×D	− 401.7	29.36	− 0.320	271.7	45.9
	Genotype	− 22.7	1.51	− 0.019	7.8	40.4
	Inbred	− 21.2	1.14	− 0.018	7.3	39.7
	Hybrid	− 21.8	1.47	− 0.018	8.0	40.6
Zein	F×F	− 21.3	1.41	− 0.017	8.1	41.9
	D×D	− 17.4	1.22	− 0.015	6.9	40.0
	(FF+DD)/2	− 19.4	1.31	− 0.016	7.6	41.0
	F×D	− 23.8	1.59	− 0.020	8.3	40.3

表 3. 主要性狀之相關係數

Table 3. Correlation coefficients among 7 characters.

Character	Zein	Yield	KW LGR	Zein LGR	KW EFPD	Zein EFPD
KW	0.39**	0.77**	0.28**	0.12	− 0.01	0.00
Zein		0.25**	0.12	0.21*	0.03	0.26**
Yield			0.15	− 0.08	− 0.13	0.07
KW. LGR				0.42**	− 0.73**	− 0.20*
Zein. LGR					− 0.18*	− 0.65**
KW. EFPD						0.08

*, ** : significant at p=0.05 and 0.01 levels, respectively.

二、各項性狀間之相關分析

七個性狀中，粒重、zein 蛋白含量及子粒產量彼此間均有極顯著之正相關；而KW與KW•LGR 間及 Zein 與 Zein•LGR 間亦分別呈極顯著及顯著之正相關。此外， KW•LGR 與 Zein•LGR 間亦呈極顯著之正相關。就有效充實期（EFPD）而言，除 Zein 與 Zein•EFPD 爲極顯著正相關外，與其他性狀間之相關大多不顯著或呈負相關，尤以 KW•LGR 與 KW•EFPD 及 Zein•LGR 與 Zein•EFPD 均呈極顯著負相關最爲明顯（表 3）。

三、不同粒型組合間各性狀之平均值及雜種優勢之比較（表 4）

（一）各性狀平均值

七個性狀中除 KW•EFPD 及 Zein•EFPD 外，均以異粒型組合大於同粒型組合；同粒型組合中，又有硬粒種組合（F×F）大於馬齒種組合（D×D）之趨勢。

（二）各性狀雜種優勢

雜種優勢與上述平均值之情形類似，除 KW•EFPD 及 Zein•EFPD 外，其餘各性狀仍以異粒型組合大於同粒型組合；而同粒型組合中，除子粒產量及 KW•LGR 外，硬粒種組合（F×F）均有較馬齒種組合（D×D）爲優的雜種優勢表現。

表 4. 不同粒型組合 F_1 雜種之各項性狀平均值及其雜種優勢

Table 4. Means and heterosis for 7 characters among hybrids of different kernel forms.

Item	Hybrid Combination	KW (mg/kernel)	Zein (mg/kernel)	Yield (g/plant)	KW LGR (mg/day/kernel)	Zein LGR (mg/day/kernel)	KW EFPD (days)	Zein EFPD (days)
Mean	F×F	308	7.66	1,594	10.05	0.40	34.0	18.5
	D×D	298	6.09	1,558	9.35	0.48	34.5	17.6
	(FF+DD)/2	303	6.88	1,576	9.70	0.44	34.3	18.1
	F×D	316	7.27	1,710	10.61	0.48	32.6	16.6
Heterosis	F×F	19.4	31.5	45.8	− 1.0	− 9.4	14.5	52.2
	D×D	13.6	7.9	79.2	0.2	− 25.1	13.9	22.6
	(FF+DD)/2	16.5	11.8	62.5	− 0.4	− 17.3	14.2	37.4
	F×D	21.5	17.0	75.1	9.1	− 3.2	9.1	28.7

討　　論

Zein 是玉米子粒中，酒精溶性（alcohol-soluble）的貯藏性蛋白質 (15) ，其在子粒中之累積量除品種間有差異外 (23,24,25) ，尙受氮肥，尤其銨態氮肥之影響 (14,17,24) 。Tsai氏等 (23,24) 更認爲zein是玉米子粒中，最主要的氮素積儲（N-sink），提高氮素之施肥量，會顯著提高子粒中 N-sink 之容量，可促進光合速率及蔗糖（sucrose）往子粒中之轉移，因而增進子粒乾物之累積。因此， zein蛋白在子粒中之累積量及累積期，決定了子粒中乾物的累積量及累積期，直接影響子粒之粒重及最終產量。

Murphy 與 Dalby (13) 指出，玉米子粒中 zein 蛋白的合成與澱粉之累積，在時間上及速率上均極爲相近，即均自受粉後約12天起急速增加。本試驗結果顯示，子粒乾重與子粒 zein 蛋白之累積曲線，走勢頗爲相似，惟根據二次迴歸方程估算結果，粒重之最高累積量出現期約在受粉後第46天，

而 zein 蛋白的最高累積量出現期約在受粉後第 40 天；亦即玉米子粒在受粉後第 12 天起，做爲主要 N-sink 的 zein 蛋白與子粒之乾重均同時快速累積，而至受粉後第40天，主要 N-sink 之容積已達飽和，而乾物之累積尚持續了約 6 天左右，惟此時乾重累積速率已趨緩慢，顯示 zein 蛋白之累積停止後，迅即影響子粒乾重之增加。

在自交系與雜交種（F_1）間，雜交種無論 zein 蛋白或粒重之最高累積量（8.0 及 265.2mg/kernel）均較自交系（7.3 及 228.5mg/kernel）爲高（表2）。就 zein 蛋白之累積差異而言，雜交種有較自交系爲快的直線累積速率（b_1 值爲1.47 及 1.14）與稍長的累積期（40.6天及39.7天）；就子粒乾重之累積差異而言，主要在於累積期（雜交種爲47.5天，而自交系爲43.7天）。換言之，自交系及雜交種間， zein 蛋白含量之差異，主要受累積速率及累積期之影響；而子粒乾重之差異，則受累積速率之影響不若累積期之影響爲大。

至於雜交種 F_1 不同粒型組合間， zein 蛋白含量或子粒乾重之差異，主要受直線生長速率之影響；異粒型組合（F×D）之 zein 蛋白含量及子粒乾重均較同粒型組合之平均值〔(FF+DD)/2〕爲大，此乃由於異粒型組合具有較大的直線生長速率（b_1 值）所致（表2）。

粒數及粒重是玉米子粒產量主要構成因素 [6,21,22,27]。粒重除與上述 Zein 蛋白含量（即主要的 N-sink）之高低有關外 [23,24,25]，主要受直線生長速率 [5,10,16,19] 及有效充實期之影響 [5,10]。許多報告顯示玉米子粒產量與有效充實期呈極顯著正相關 [4,8,20]。本試驗相關分析顯示，玉米子粒產量與粒重及 zein 蛋白含量間，也有極顯著之正相關，而粒重與 zein 蛋白含量間之關係亦然。粒重及 zein 蛋白含量各與其本身的直線累積速率（LGR）成極顯著及顯著的正相關，而 KW • LGR 與 zein • LGR 間亦爲極顯著的正相關，表示粒重及 zein 蛋白之累積，具有同時進行而維持一定比值之關係。本試驗中，有效充實期對子粒乾重及產量之影響較直線生長速率爲次要，且有呈負相關之情形，此可能因本省春作玉米之栽培環境爲早期低溫、短日照，因此，營養生長期較長，其乾物生長呈早期强勢型（early vigor）[2]；但至生殖生長後期，因高溫、强日照，促使植株加速老化，營養生長期中累積之乾物，必需在較短時間內快速轉移，方能獲得較大的產量，是以春作環境下 LGR 影響子粒乾重之累積較 EFPD 更爲明顯而重要。至於秋作之表現型式爲何，有待進一步之探討。

玉米爲典型異交作物，具有雜種優勢現象。雜種優勢之大小，通常與親本血緣之遠近 [7,9,26] 或遺傳的歧異性（genetic divergency）[12,18] 有關。本試驗利用溫帶馬齒種及熱帶硬粒種玉米種源間之不同雜交組合，進行比較，發現大多數性狀均以異粒型組合較同粒型組合爲優異（表4），亦即本試驗所使用之馬齒種及硬粒種種源間，具有優異之雜種優勢存在，可爲高產玉米雜交種組合之模式。同時，試驗結果亦顯示，同粒型組合中，硬粒種組合較馬齒種組合有較優之表現，因此，在雜交種子採種時，如以硬粒種組合或自交系爲母本，將可獲得較佳之採種量。

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Zein Content, Kernel Weight and Grain Yield of Dent and Flint Forms of Maize[1]

Jou-ruey Juang[2], Ying-chuan Lu[2] and Tzong-chia Lee[3]

Summary

Each of four dent and flint kernel forms of maize inbreds and their 28 diallel hybrids were used in replicated experiment during spring crop 1984 at Taichung to study the relationship of zein accumulation to kernel weight and grain yield, as well as their differences among kernel forms.

The results showed that the shapes of the accumulative curves, derived from quadratic regression equations for both zein and dry matter accumulations, were closely synchronized and controlled by both linear growth rate (LGR) and effective filling period duration (EFPD).

The difference between inbred and F_1 hybrid in zein accumulation was also controlled by both LGR and EFPD. However, it was primarily controlled by EFPD in dry matter accumulation of the kernels. In other words, hybrids performed better than inbreds in zein and dry matter accumulations was due to greater in LGR and EFPD, and EFPD, respectively.

On the other hand, the differences among F_1 hybrids in zein and dry matter accumulations were primarily due to LGR. This indicated that LGR was more important in determining the accumulative curves for both zein and dry matter, and varieties with greater LGR in zein and dry matter accumulations of the kernel have higher yield potential during spring crop.

Highly significantly positive correlations between zein content and kernel weight, and among zein content, kernel weight and grain yield were found. Highly significantly and significantly positive correlations between kernel weight and kernel linear growth rate; zein content and zein linear growth rate, respectively, were also found. This indicated the importance of zein synthesis in maize kernel in affecting kernel linear growth rate, kernel dry weight and grain yield.

The means and heterosis of seven characteristics including kernel weight, zein content, grain yield, kernel-LGR, and zein-LGR, except kernel-EFPD and zein-EFPD, were higher in hybrid combinations between kernel forms (ie., dent×flint) than those within kernel forms [ie., flint×flint, dent×dent or (flint×flint+dent×dent)/2], indicating a super heterosis pattern existed between germplasms of flint and dent kernel forms for high yield hybrids development.

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Genetic Variation of Soybean Hybrid Populations by Natural Selection in Spring Crop Season at Four Locations[1]

I. Frequency Distributions for Certain Agronomic Characters in F_2 Generation

Kuo-lein Chan, Ruey-shing Lee and Fu-sheng Thseng[2]

Abstract: In spring crop season 1983, two F_2 soybean (*Glycine max*) hybrid populations, KS8×TN15 (Population A) and TN15×T175 (Population B) were planted in four locations of Taiwan for studying the frequency distributions and breeding parameters of eleven characters in F_2 populations. The distribution patterns showed late flowering in Tainan and Taichung locations, whereas those in Pingtung and Hsinchu flowered earlier. All characters studied distributed continuously but varied among locations. The standard deviations of plant height, nodes on main stem, days to flowering and days to maturity tended to be increased from south toward north. The results suggested that some differentiation in F_2 populations under various locations were involved.

Introduction

A hybrid population of self-pollinated crop advanced for several generations under varied environments would be a very useful way in the study of evolution, adaptation, breeding parameters, and genetic variation of the crop. Selection can be carried out in early generation and characters desired can be selected and individual plants enable fully to express their potential characteristics when hybrid populations are advanced under favorable environments [1,5,6,14]. Evidence showed that environmental effect on the characteristics of a bulk populations usually occurred [1]. The genetic parameters as correlation, heritablilty and inheritance mode may be significantly changed when hybrid populations of crops are subjected to natural selections [2,4,5,7,12,15,16,17,18,19]. Moreover, variable environments may influence selection efficiency [13,16,17,18] and create variant biotypes [6,7,8].

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Three crops of soybeans, namely spring, summer and fall (in southern-most that only) crop seasons can be adapted in Taiwan[9,10,11]. Significant association between crop season and variety consistently existed[12,17]. Invirtually, soybean breeding in Taiwan has totally done in two successive seasons each year——which is called the disruptive seasonal selection[13,18], but it has rarely done on direction seasonal selection. Significance on these two soybean breeding schemes under different planting seasons and locations is an urgent matter that must be solved soon as possible.

Soybean is rather sensitive to environmental factors. It grows island-wide in Taiwan. Though Taiwan is a tiny island, its weather differs greatly from north down south resulting from its long and narrow leaf-shaped geographic nature. Consequently, the planting time of soybeans varied with locations and the varieties adapted to particular areas are required. Therefore, to study the relationship between environment and soybean breeding in Taiwan is of great important event.

The main purpose of this experiment was to study the genetic variation and breeding parameters by growing two soybean hybrid populations from F_2 to F_5 generations at four locations and in two crop seasons (spring and fall) each year. We are in great hope that the result might suggest the most suitable soybean breeding locality and selection method in Taiwan. This paper reports the variation of frequency distributions of several agronomic characters in two F_2 soybean populations in spring crop season 1983 at four locations.

Materials and Methods

Two F_2 soybean populations, KS8×TN15 (Population A) and TN15×T175 (Population B), were grown during the spring season 1983. A total of 1,000 to 2,000 F_2 and 100 parental seeds were sown (1 seed per hill) respectively on March 1 at Kaohsiung District Agricultural Improvement Station (Kaohsiung DAIS), located in Pingtung, southern-most of Taiwan, on February 4 at Shanhua, Tainan, south-west of Taiwan, on March 1 at Taiwan Agricultural Research Institute (TARI), Taichung, middle-west of Taiwan, and on March 13 at Hsinchu (Taoyuan DAIS), northern part of Taiwan. Local cultural practice was adopted for the management of the experimental field work. Measurements were randomlg made from 500 F_2 and 50 parental plants for plant height, number of branches, nodes on main stem, pods of branches, pods on main stem, number fo seeds, days to flowering, days to maturity, seed weight, total pods, and 100-seed weight.

Experimental Results

F_2 distributions and means and standard errors for the eleven characters measured in populations A and B at four locations were shown in Figs. 1 to 11. A detailed description for each of them are as follows:

1. Plant height (Fig. 1)

The F_2 distribution for plant height are shown in Fig. 1. The continuously and transgressively segregations toward tall parents were found in four experimental locations. In population A, this character gave bimodal distributions in Tainan, Taichung

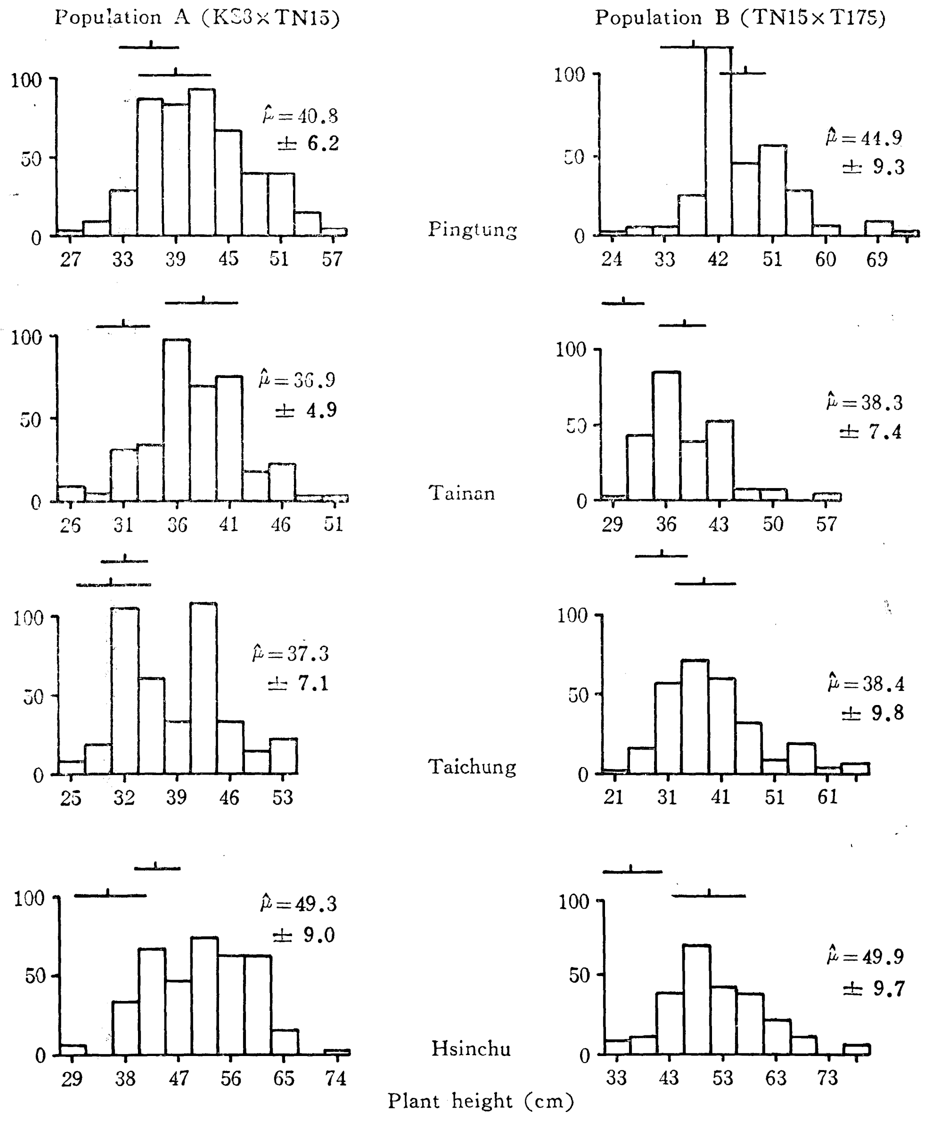

Fig. 1. F_2 distributions of plant height in four locations. Symbol (-⊥-) indicates the parental means with standard error.

and Hsinchu locations. The variability was larger in Hsinchu, moderate in Taichung, and smaller in Tainan. Complete dominance was showed in Pingtung, partial dominances in Tainan and Hsinchu, and over dominance in Taichung location resulting from their mean values were equal, intermediate and above to their parents.

Compared to population A, distribution patterns in population B showed wider variation and larger mean values in four locations. This character gave continuously and transgressively segregations in Pingtung and Taichung locations. Character of plant height showed a bimodal curve in Pingtung and Tainan, and a positive skewness distribution

in each of the four locations. Partial dominances were showed in four locations based on the mean values of plant height.

2. Number of branches (Fig. 2)

The F_2 distributoins with respect to branch number are shown in Fig. 2. Continuous and transgressive variations showed in four locations in population A. In addition, there was a positive skewness distribution in Hsinchu, and approximate-normal distributions in Pingtung, Tainan and Taichung locations. Dispersion for branch number were larger in Tainan and Hsinchu, and smaller in Taichung. The F_2 population means

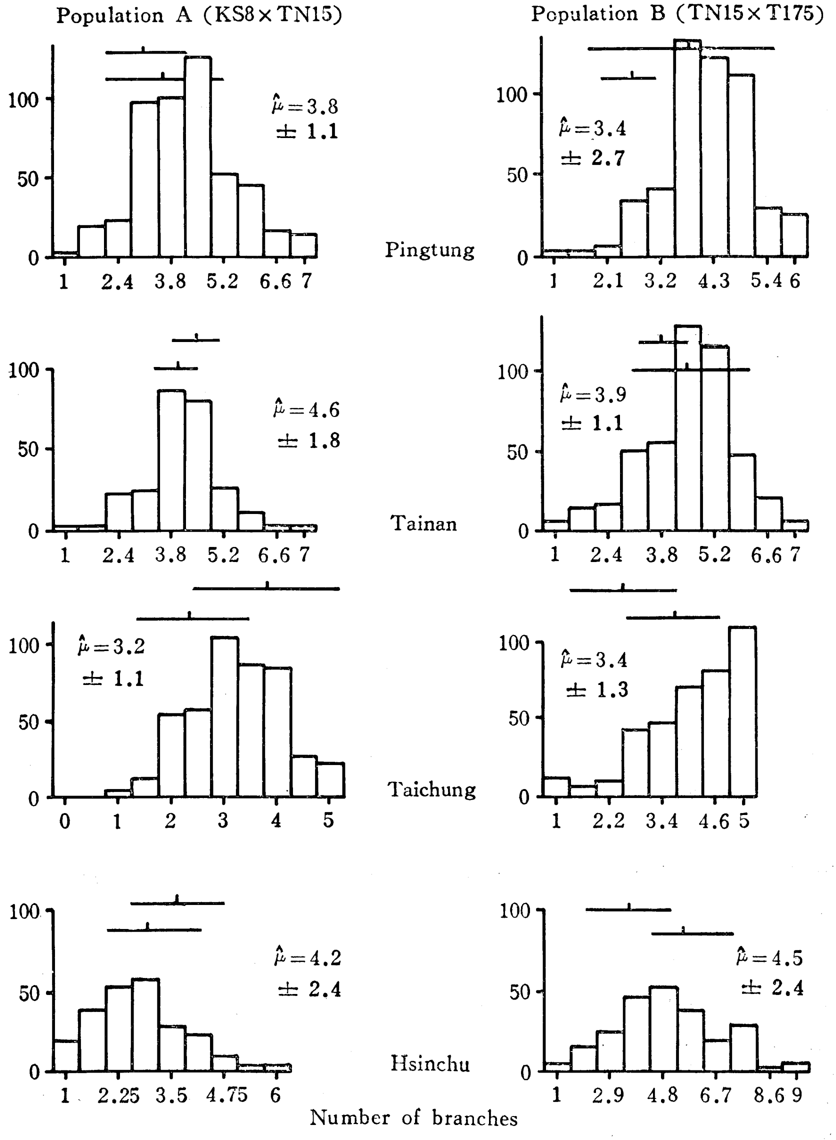

Fig. 2. F_2 distributions of branch number in four locations. Symbol (⊥) indicates the parental means with standard error.

showed over dominances in Pingtung, and partial dominance in Taichung and Hsinchu locations.

Continuous and transgressive distributions showed in Pingtung in population B. A negative skewness curve occurred in Taichung, and approximate-normal distributions in Tainan and Pingtung, and a bimodal curve in Hsinchu. This character gave wider distribution in Pingtung, Hsinchu, and narrow in Tainan. The F_2 population means indicated a quantitative type of inheritance with branch number being partial dominant in Pingtung, Tainan and Hsinchu, and over-dominant in Taichung.

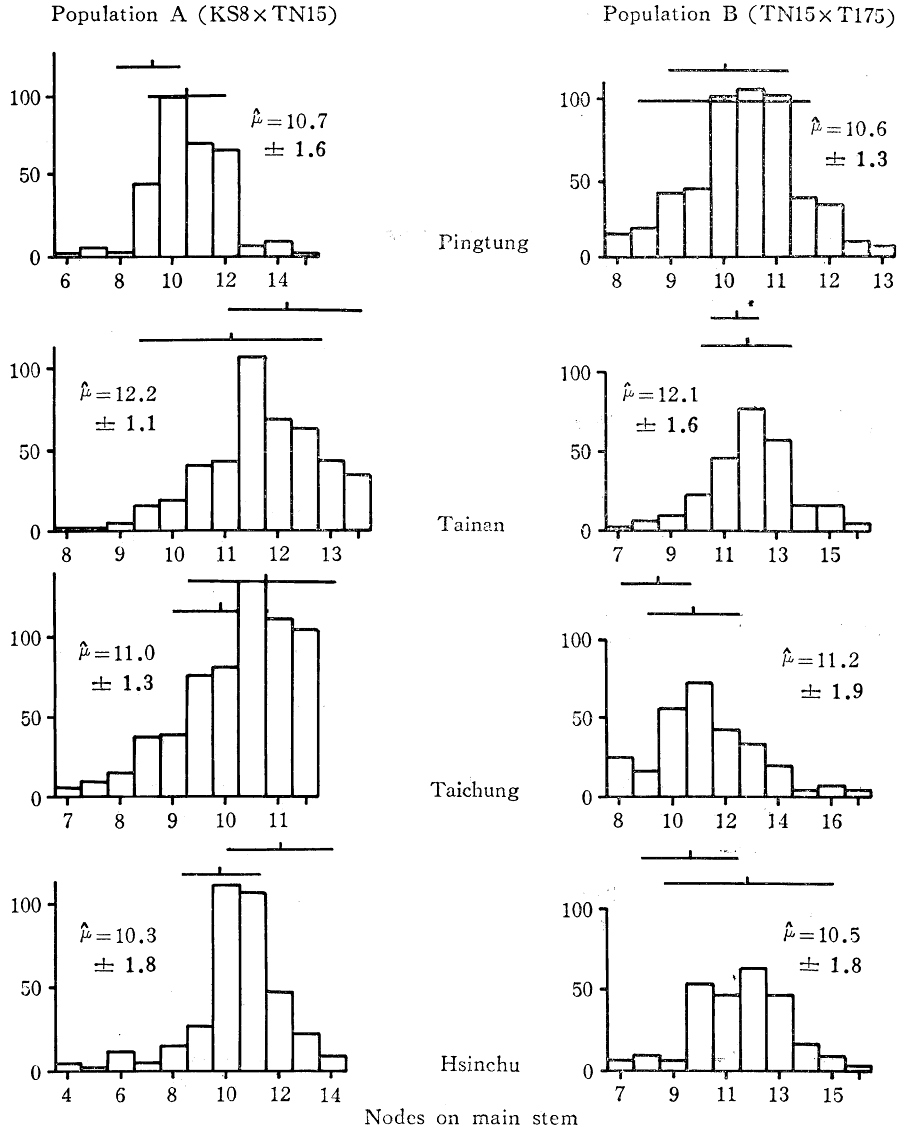

Fig. 3. F_2 distributions of nodes on main stem in four locations. Symbol (⊥) indicates the parental means with standard error.

3. Nodes on main stem (Fig. 3)

The F_2 populations showed continuously and transgressively segregation in node number with a unimodal curve in Pingtung location in population A. Negative skewness curve showed in Taichung. Its dispersion was larger in Hsinchu, smaller in Tainan. The F_2 mean values for node number showed that complete dominances were involved in Tainan. Similarity, continuous distributions showed in population B in all four locations. Except for Taichung, node number was not segregated transgressively in other three locations. The F_2 populations distributed approximately-normal in Pingtung

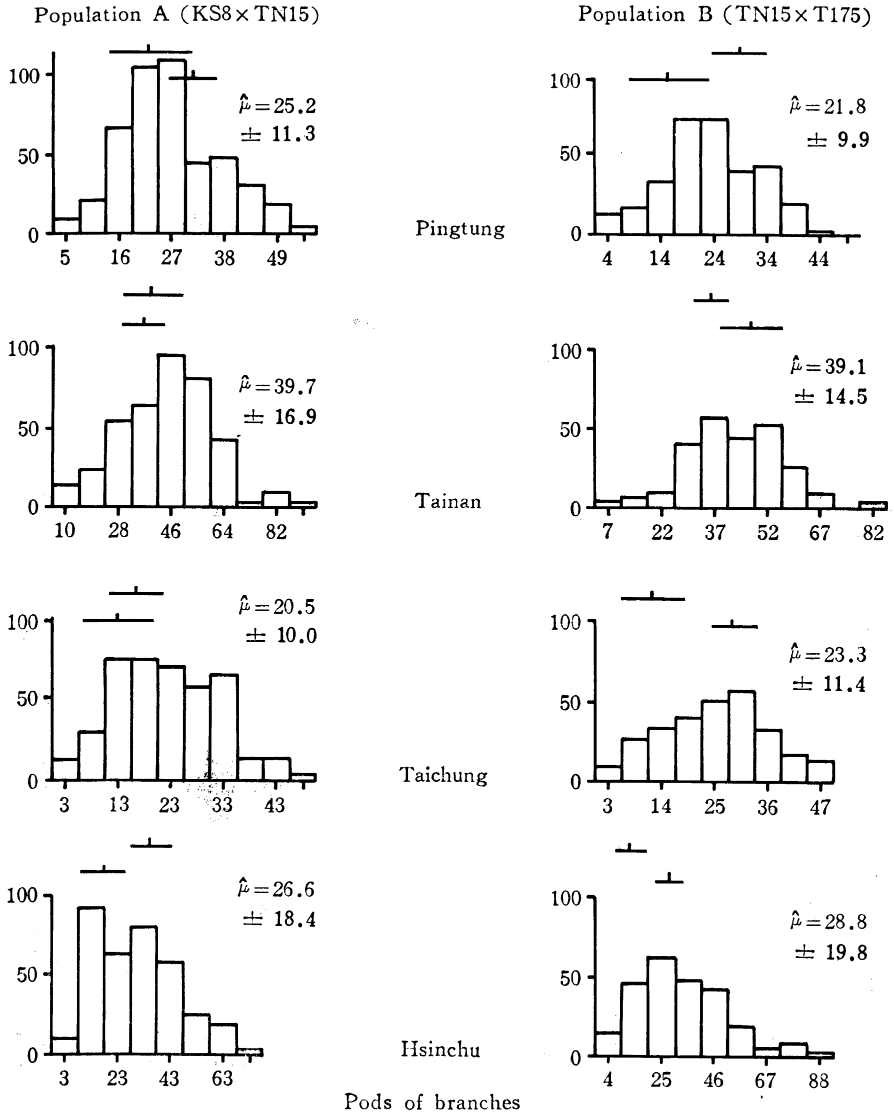

Fig. 4. F_2 distributions of pods of branches in four locations. Symbol (┴) indicates the parental means with standard error.

and Tainan, and a positive skewness curve in Taichung, a bimodal curve in Hsinchu. The F_2 population means showed that partial dominance for node number involved in Pingtung and Hsinchu locations. This character gave larger dispersion in Taichung, moderate in Hsinchu, and smaller in Pingtung.

4. **Pods of branches** (Fig. 4)

In population A, the F_2 populations were continuously and transgressively distributed with pods of branches in Tainan and Taichung locations, but no transgressive segregations in Hsinchu and Pingtung were observed. Fig. 4 showed that skewness curve toward more pods in Pingtung and Hsinchu, and toward less in Tainan were found. Larger dispersion showed in Hsinchu, moderate in Tainan and smaller in Taichung location. Incomplete dominances showed in Pingtung, Tainan and Hsinchu locations resulting from their mean values of this character.

Similarity, population B also distributed continuouosly. No transgressive segregations were found except in Hsinchu location. This character gave bimodal curve in Tainan, negative skewness in Taichung and positive skewness curve in Hsinchu. Incomplete dominance were found in all the four locations. This character dispersed largely in Hsinchu, moderately in Tainan, and small in Pingtung.

5. **Pods on main stem** (Fig. 5)

This character gave continuously and transgressively with positive skewness distributions in population A. Its dispersion was large in Hsinchu, moderate in Tainan, and small in Taichung. The means of F_2 populations showed complete dominance in Pingtung, over dominance in Taichung, and incomplete dominance in Tainan and Hsinchu locations.

In population B, continuous distributions also showed in four F_2 populations, but no transgressive segregations were found. This character had negative skewness curve in Pingtung, bimodal curve in Tainan. It dispersed largely in Tainan, moderately in Hsinchu, and small in Pingtung. The F_2 means were intermediate to their parents indicating incomplete dominance were involved except in Pingtung location.

6. **Number of seeds** (Fig. 6)

Continuous variable and transgressive segregations were showed in population A except in Pingtung where no transgressive segregation was found. This characted gave positive skewness curves in Pingtung and Hsinchu, and a bimodal curve in Taichung. The dispersion was large in Tainan, moderate in Pingtung, and small in Taichung location. Except in Pingtung the means of number of seeds in other three locations, Tainan, Taichung and Hsinchu showed overdominances for this character.

In population B, the frequency distribution showed continuously and transgressively only in Hsinchu location. This character gave positively skewness distributions in Tainan and Hsinchu locations, and appoximate-normal distribution in Pingtung. The dispersion was large in Hsinchu, mdoerate in Tainan, and small in Pingtung. The F_2 means showed that partial dominance in Pingtung, Tainan and Taichung locations.

7. **Days to flowering** (Fig. 7)

In population A, the distributions of days to flowering showed continouosly in four

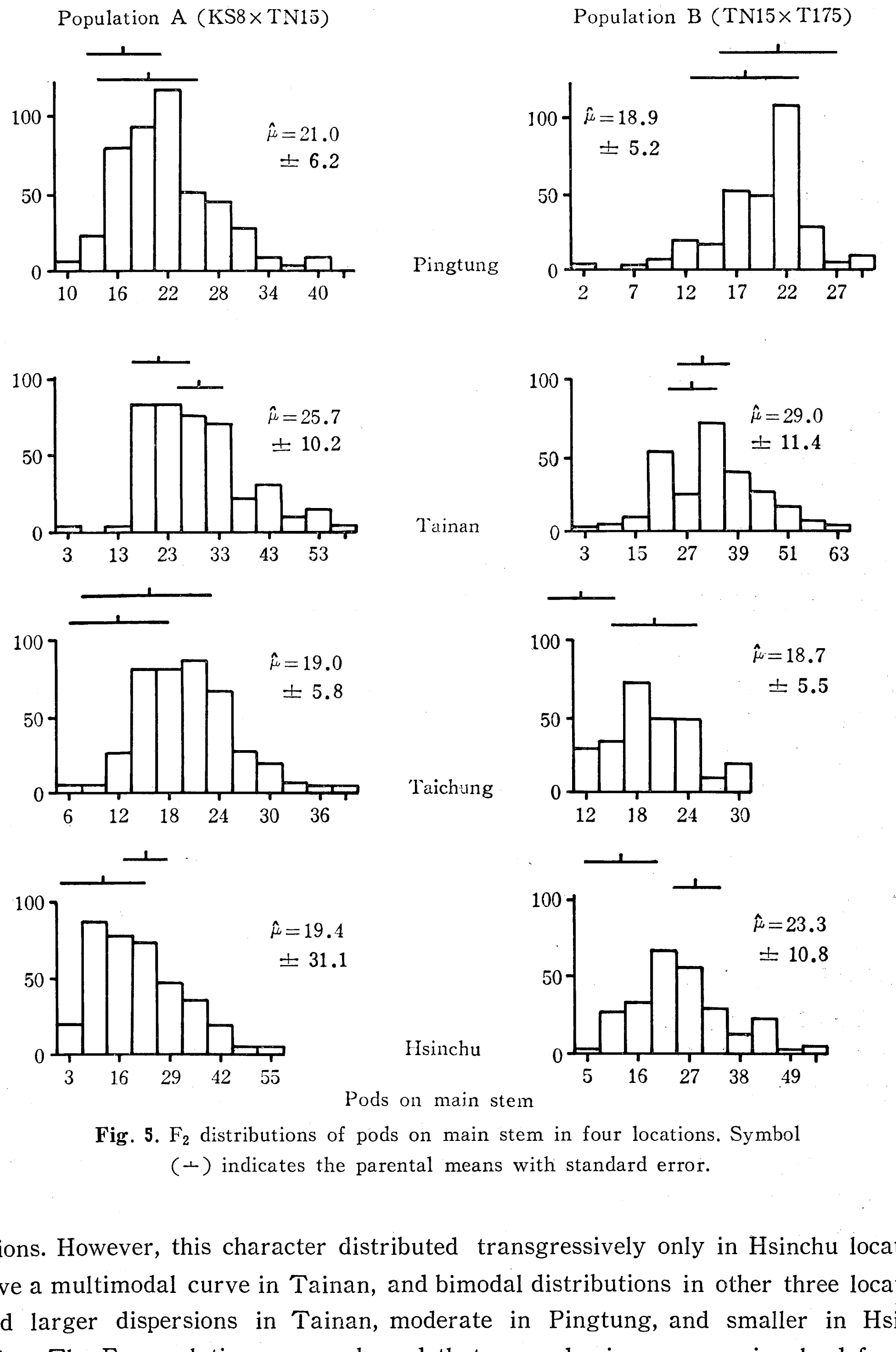

Fig. 5. F_2 distributions of pods on main stem in four locations. Symbol (⊥) indicates the parental means with standard error.

locations. However, this character distributed transgressively only in Hsinchu location. It gave a multimodal curve in Tainan, and bimodal distributions in other three locations. It had larger dispersions in Tainan, moderate in Pingtung, and smaller in Hsinchu location. The F_2 population means showed that over dominance were involved for days to flowering in Pingtung, Taichung and Hsinchu locations.

F_2 distributions in population B were pretty much the same in population A. Its dispersion was larger in Tainan, smaller in Pingtung location. The mean values showed that overdominance was involved only in Tainan location.

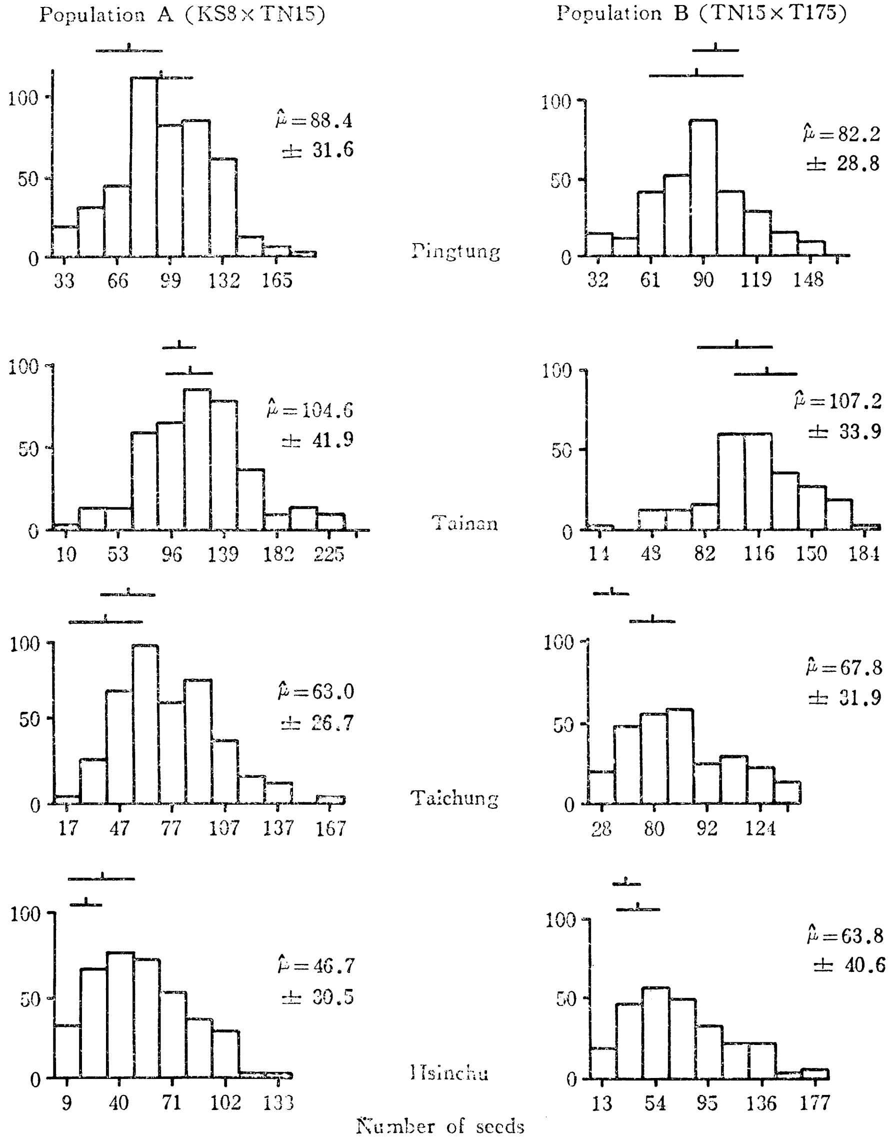

Fig. 6. F_2 distributions of number of seeds in four locations. Symbol (⊥) indicates the parental means with standard error.

8. Days to maturity (Fig. 8)

In population A, continuous and multimodal frequency distributions for days to maturity were found in four locations. Except in Hsinchu location, the segregations were positively skewed in other three locations. Population A gave larger dispersion in Hsinchu, moderate in Taichung, and smaller in Tainan. The distribution patterns in population B differed greatly with those in population A. Transgressive segregations and partial dominances for this character were showed in all four locations. The dispersion was larger in Hsinchu, moderate in Tainan, and smaller in Pingtung location.

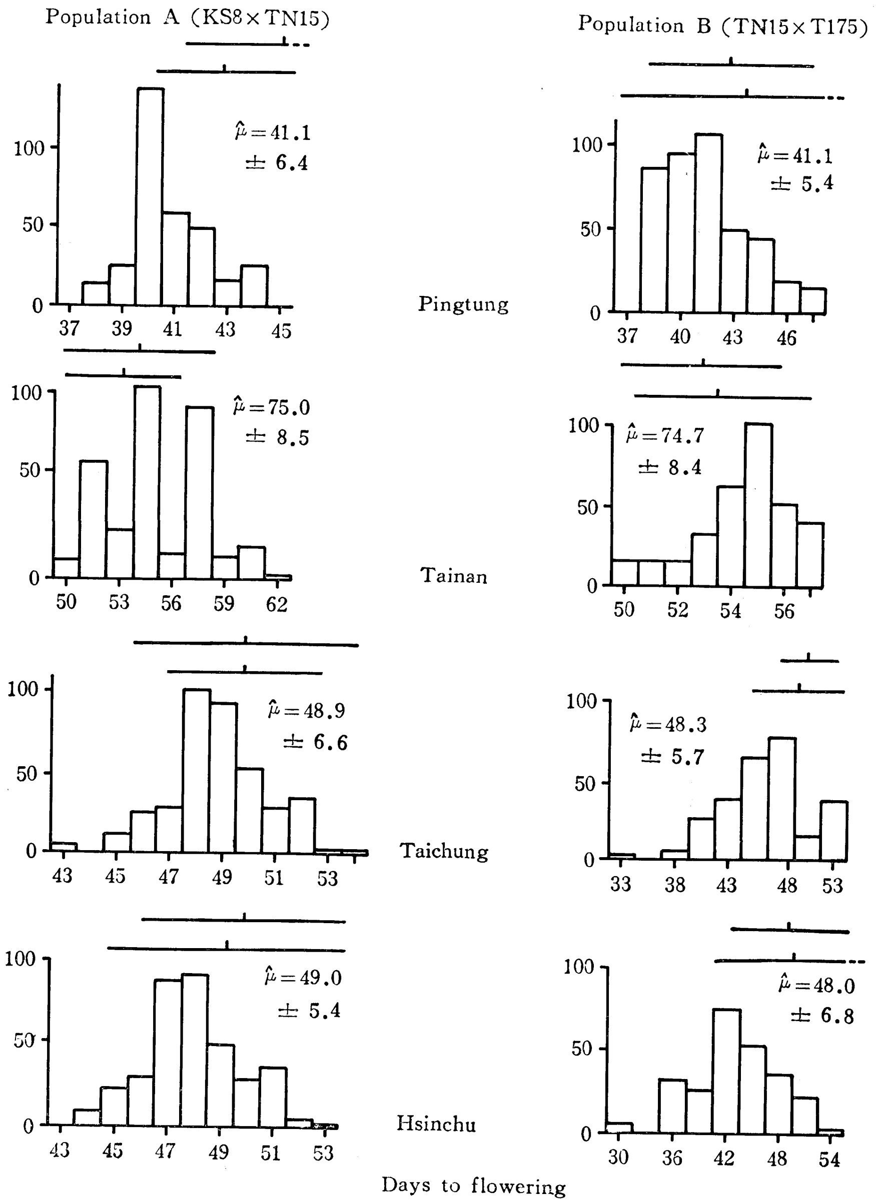

Fig. 7. F_2 distributions of days to flowering in four locations. Symbol (⊥) indicates the parenal means with standard error.

9. **Seed weight** (Fig. 9)

The F_2 populations distributed continuously and transgressively in population A in four locations. The distribution curves were positively skewed in Taichung and Hsinchu locations. It gave larger dispersion in Taichung, moderate in Tainan and smaller in Hsinchu location. The F_2 means showed overdominant inheritance for this character in Taichung, and incomplete dominances in other three locations. Though this character

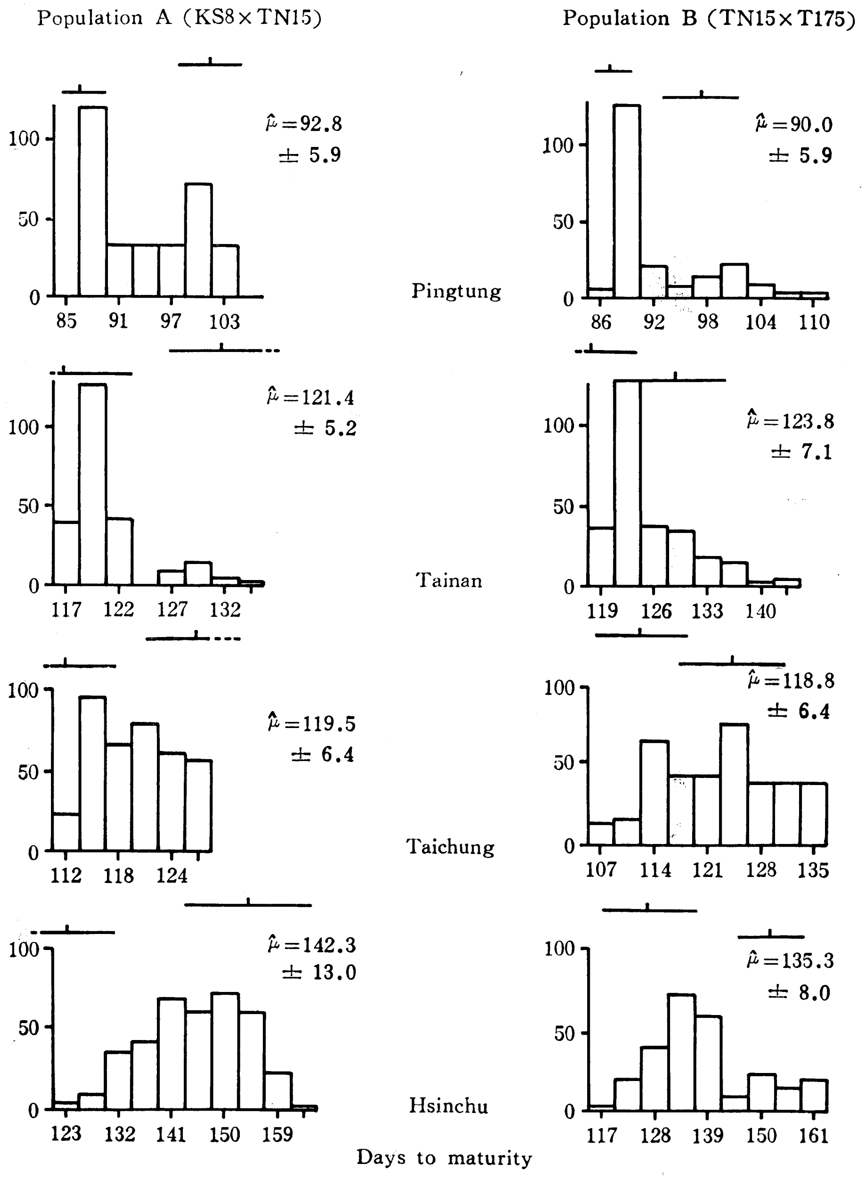

Fig. 8. F_2 distributions of days to maturity in four locations. Symbol (⊥) indicates the parental means with standard error.

distributed continuously in population B in four locations, it distributed transgressively only in Hsinchu. And the distribution curves were positively skewed in Taichung and Hsinchu locations. Its dispersion was large in Hsinchu, moderate in Tainan, and small in Pingtung. The mean values of F_2 showed that incomplete dominances were involved in four locations.

10. Total Pods (Fing. 10)

In population A, continuous variable and transgressive segregation was found only in Taichung location. The F_2 populations showed approximate-normal distributions in

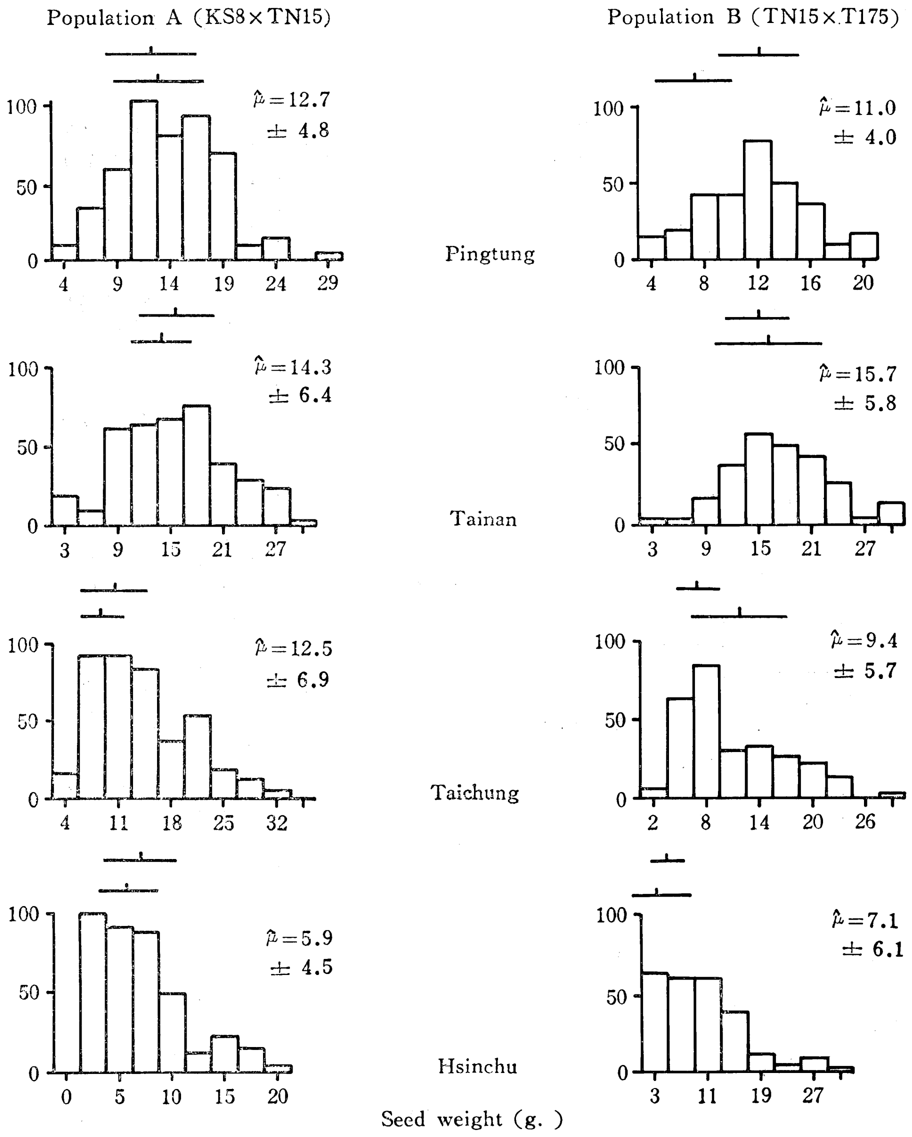

Fig. 9. F_2 distributions of seed weight in four locations. Symbol (⊥) indicates the parental means with standard error.

Pingtung and Tainan, and a positive skewed curve in Hsinchu. This character dispersed largely in Hsinchu and Tainan, and small in Taichung. The F_2 means showed that overdominance in Taichung and incomplete dominances in Pingtung and Tainan locations were found for this character.

Similar in dirtribution patterns were showed in population B. This character distributed approximately-normal in Pingtung and Tainan locations. Total pods gave larger dispersion in Hsinchu, moderate in Tainan, and small in Pingtung. The F_2 means

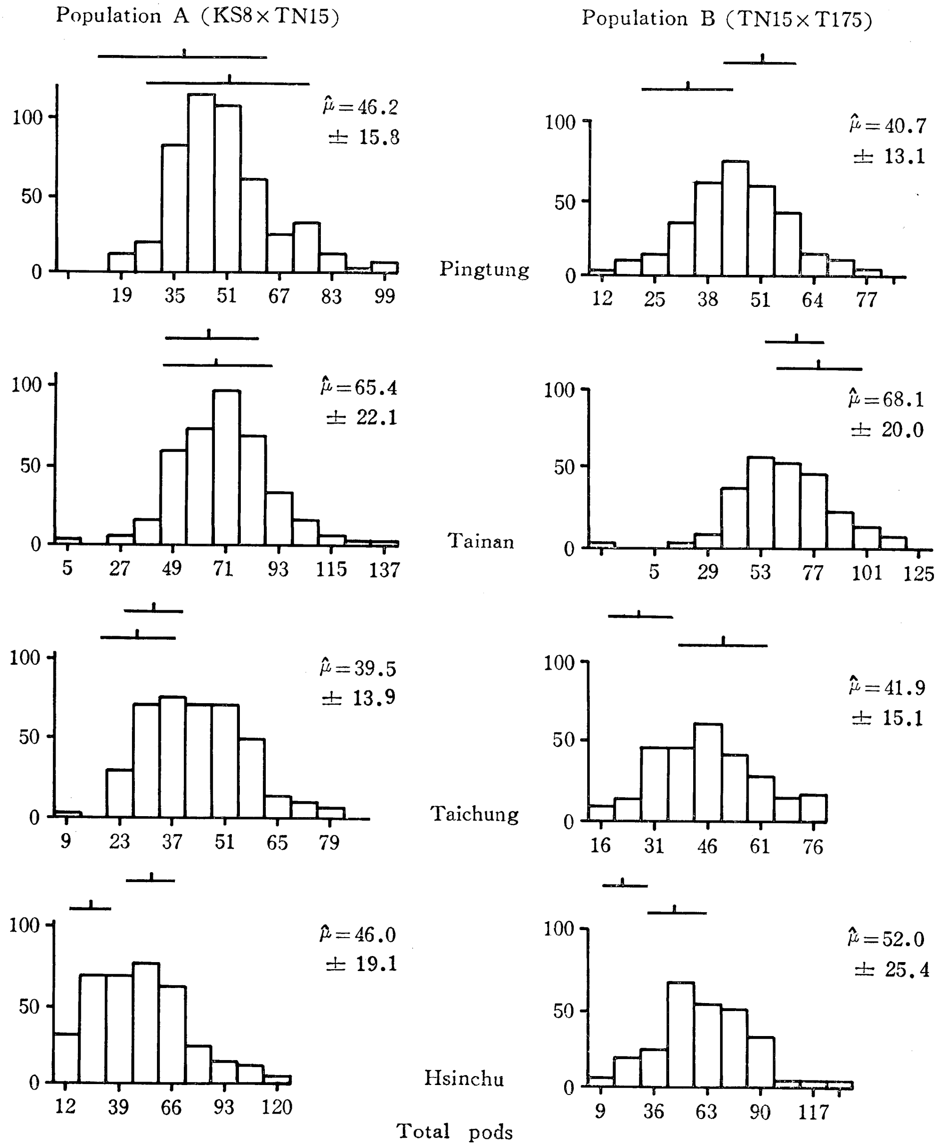

Fig. 10. F_2 distributions of total pods in four locations. Symbol (⊥) indicates the parental means with standard error.

indicated that partial dominances were involved in all four locations.

11. **100-seed weight** (Fig. 11)

F_2 populations in both populations showed continuously segregations in four locations. Except for Hsinchu location in population B, no transgressive distributions were found. This character distributed approximately-normal in Tainan and positively skewness in Pingtung location in population A. It gave larger dispersion in Hsinchu and Taichung, and smaller in Tainan.

In population B, this character distributed positively skewness in Pingtung and Ta-

ichung, and bimodal in Hsinchu location. Its dispersion was larger in Taichung, smaller in Pingtung. The F_2 mean values in both populations indicated that incomplete dominances were involved except for Tainan in population A.

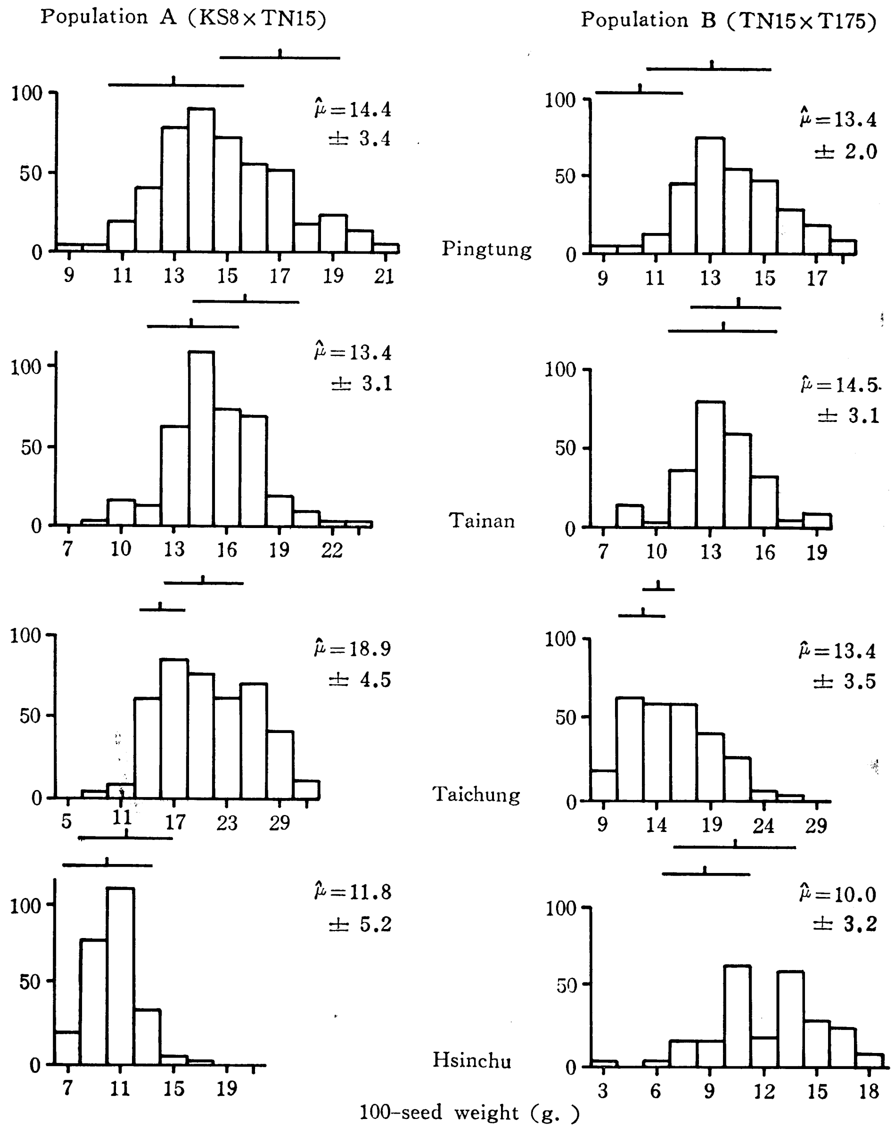

Fig. 11. F_2 distributions of 100-seed weight in four locations. Symbol (-ı-) indicates the parental means with standard error.

Discussion

The existance of genotype-environmental interaction is well known in crop plants. A genotype grown in diferent environments may cause different responses. Consequently, when a hybrid population was grown in different environments, inconsistent

phenotypes may appear owing to the interaction of genotype and environment. In other words, the change of environmental factors may vary the genotypes. Previous researchers[1,7,14] pointed out that a significant difference of hybrid population distribution patterns from various locations often occurred. Same trends of frequency distributions for certain characters were found in this experiment. The degree of genetic variability of each characters within the population is inversed in proportion to locations. Marked differences among distributions arose not ony in populations and agronomic characters, but also in locations tested. Of the four locations temperature was rather low in Hsinchu, northern part of Taiwan, during the early growing stage in spring season. However, temperature was rather high in Pingtung, southern part of Taiwan, at the same period. This indicates that geographic/local differences apparently existed in this study. Thus it is with the experiment results.

Several investigators[2,3,4,6] have pointed out that micro-differentiation may arise within the plant population due to the change of, even the minimal environmental factors. Therfore, the population variability observed can be considered the differentiation for each F_2 population under each environment force, or natural selection. In general, the plant population subjected to longer natural selection, the longer efficiency and more prominent results would appear. Futhermore, there is a close relationship among natural selection and correlation intensity and direction of the agronomic characters involved. More information will be obtained with the advancement of progeny generations added.

Acknowledgement

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春作單向及不同栽培地區之自然淘汰對大豆雜種集團育種行爲之影響[1]

I. F_2 世代農藝性狀頻度分布之變異

詹國連 李瑞興 曾富生[2]

摘　要

使用 KS8×TN15（A集團）及 TN15×T175（B集團）兩個大豆雜種集團之 F_2 種子，於1983年春作分別播種於臺灣四個地區，探討 F_2 集團之農藝性狀，在四個不同栽培地區之集團分布型及各種育種介量。

兩個 F_2 集團之分布型，在臺南及臺中地區偏向晚開花，在屏東及新竹偏於早開花。所有調查性狀均呈連續性之分離，且分布型在不同栽培地區間均有顯著差異。而株高、分枝數、主莖節數、開花期及成熟期等性狀之集團的分散度，一般呈現由南向北增大之趨勢。其他性狀也因地區有顯著差異。由此結果，可推測 F_2 雜種集團因不同栽培環境之影響，似乎地區間已有分化之現象。

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Genetice Variation of Soybean Hybrid Populations by Natural Selection in Spring Crop Season at Four Locations[1]

II. Variation of Heritabilities and Correlations for Certain Agronomic Characters in F_2 Generation

Kou-lein Chan, Ruey-shing Lee and Fu-sheng Thseng[2]

Abstract: In spring crop season 1983, two F_2 soybean (*Glycine max*) hybrid populations, KS8×TN15 (Population A) and TN15×T175 (Population B) were planted in four locations of Taiwan to estimate the heritabilities and correlations for eleven agronomic characters in F_2 populations. In general, the heritability values for vegetative characters were higher than that of the yield component ones. The magnitude of heritability varied with locations, and the heritabilities of vegetative characters tended to be increased from south to north. Significant differences of correlations among characters were found. The characters in Taichung and Tainan of Population A and those in Taichung and Hsinchu of Population B were closely associated than those in other locations. These results suggested that some differentiation had taken place in the F_2 populations of this study.

Introduction

A hybrid population of self-pollinated crop advanced for several generations under varied environments would be a very useful way in the studying of evolution, adaptation, breeding parameters, and genetic variation of the crop. Several workers [1,6,7,16] reported that the characters of the crop were easy to present and the practical breeding work can be easily operated and genotypes with adaptation could be selected when hybrid populations are advanced under favorable environments. The genetic parameters as correlation, heritability and inheritance mode may be significantly changed [2,5,6,8,13,17,18,19,20,21] and variant biotypes created [7,8,9] when hybrid populations of crops are subjected

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to different environments.

Three crops of soybeans, namely spring, summer and fall (in southern-most that only) crop seasons can be adapted in Taiwan [10,11,12]. Significant association between crop season and variety consistently existed [13,18]. Invirtually, soybean breeding in Taiwan has totally done in two successive seasons each year---which is called the disruptive seasonal selection [14,20], but it has rarely done on direction seasonal selection. Significance on these two soybean breeding schemes under different planting seasons and locations is an urgent matter that must be solved soon as possible.

Soybean is rather sensitive to environmental factors. It grows island-wide in Taiwan. Though Taiwan is a tiny island, its weather differs greatly from north down south resulting from its long and narrow leaf-shaped geographic nature. Consequently, the planting time of soybeans varied with locations and the varieties adapted to particular areas are required. Therfore, to study the relationship between environment and soybean breeding in Taiwan is of great important event.

The main purpose of this experiment was to study the genetic variation and breeding parameters by growing two soybean hybrid populations from F_2 to F_5 generations at four locations and in two crop seasons (spring and fall) each year. We are in great hope that the result might suggest the most suitable soybean breeding locality and selection method in Taiwan.

In part one of this experiment, the authors [4] pointed out that significant differences occurred among the distribution patterns of agronomic characters due to different location/environmental effects. However, relationship between effect of environment and agronomic characters, and degrees of variation for each genotype, and interactions among characters remains obscure. This paper reports the variation of heritabilities and correlations for eleven characters of two F_2 soybean populations grown in spring crop season 1983 at four locations.

Materials and Methods

Two F_2 soybean populations, KS8×TN15 (population A) and TN15×T175 (population B) were grown during the spring season 1983. A total of 1,000 to 2,000 F_2 and 100 parental seeds were sown (1 seed per hill) respectively on March 1 at Kaohsiung District Agricultural Improvement Station (Kaohsiung DAIS), located in Pingtung, southern-most of Taiwan, on February 4 at Shanhua, south-west of Taiwan, on March 1 at Taiwan Agricultural Research Institute (TARI), Taichung, Middle-west of Taiwan, and on March 13 at Hsinchu (Taoyuan DAIS), northern part of Taiwan. Local cultural practice was adopted for the management of the experimental field work. Meaurements were randomly made from 500 F_2 and 50 parental plants for plant height, number of branches, nodes on main stem, pods of branches, pods on main stem, number of seeds, days to flowering, days to maturity, seed weight, total pods, and 100-seed weight.

Experimental Results

Heritability

The broad sense heritabilities for eleven characters measured were shown in Table 1. They varied greatly not only between populations, but also among characters and locations. They were high (over 70%) for plant height, branch number, nodes on main stem, days to flowering and maturity, but low for yield component characters: seed number, seed weight and total poes. In general, the more north were the experimental locations, the higher heritabilities were for plant height and nodes on main stem. In other words, they tended to be decreased from Hsinchu downward Taichung, Tainan and Pingtung. Similarity, with the exception of population A, heritability for number of branches also tended to be high in northern locations and low in southern ones. In addition, higher heritabilities for branch number and pods on main stem were obtained in Hsinchu, moderate in Taichung, and lower in Tainan and Pingtung locations. Heritabilities for seed number, total pods, and seed weignt were consistently low in four locations, and they had no significant differences among locations. As for 100-seed weight, its heritability was also high in Hsinchu, moderate in Taichung and Tainan, and low in Pingtung.

Table 1. Heritability values (%) for eleven characters of F_2 populations in four locations

Character	Pingtung		Tainan		Taichung		Hsinchu	
	Population A	Population B	Population A	Population B	Population A	Population B	Population A	Population B
Plant height	76	86	79	81	80	91	84	92
Branch number	69	72	75	76	62	83	91	89
Nodes on man stem	70	78	73	81	76	88	89	87
Pods of branches	54	69	67	72	50	71	72	74
Pods on main stiem	56	55	64	66	51	54	69	68
Seed number	65	63	68	67	50	66	63	68
Days to flowering	87	88	89	82	84	85	84	86
Days to maturity	87	79	80	81	86	72	87	84
Seed weight	60	60	62	63	67	64	60	66
Total pods	56	62	61	64	58	63	68	65
100-seed weight	69	54	69	74	76	73	80	72

Remarks: Population A: KS8×TN15. Population B: TN15×T175.

Correlations among Characters

Phenotypic correlations among characters of the two populations at four locations were shown in Figs. 1 and 2. Generally, correlations differed not only between populations but also among locations. The detailed explanation by locations were as follows:

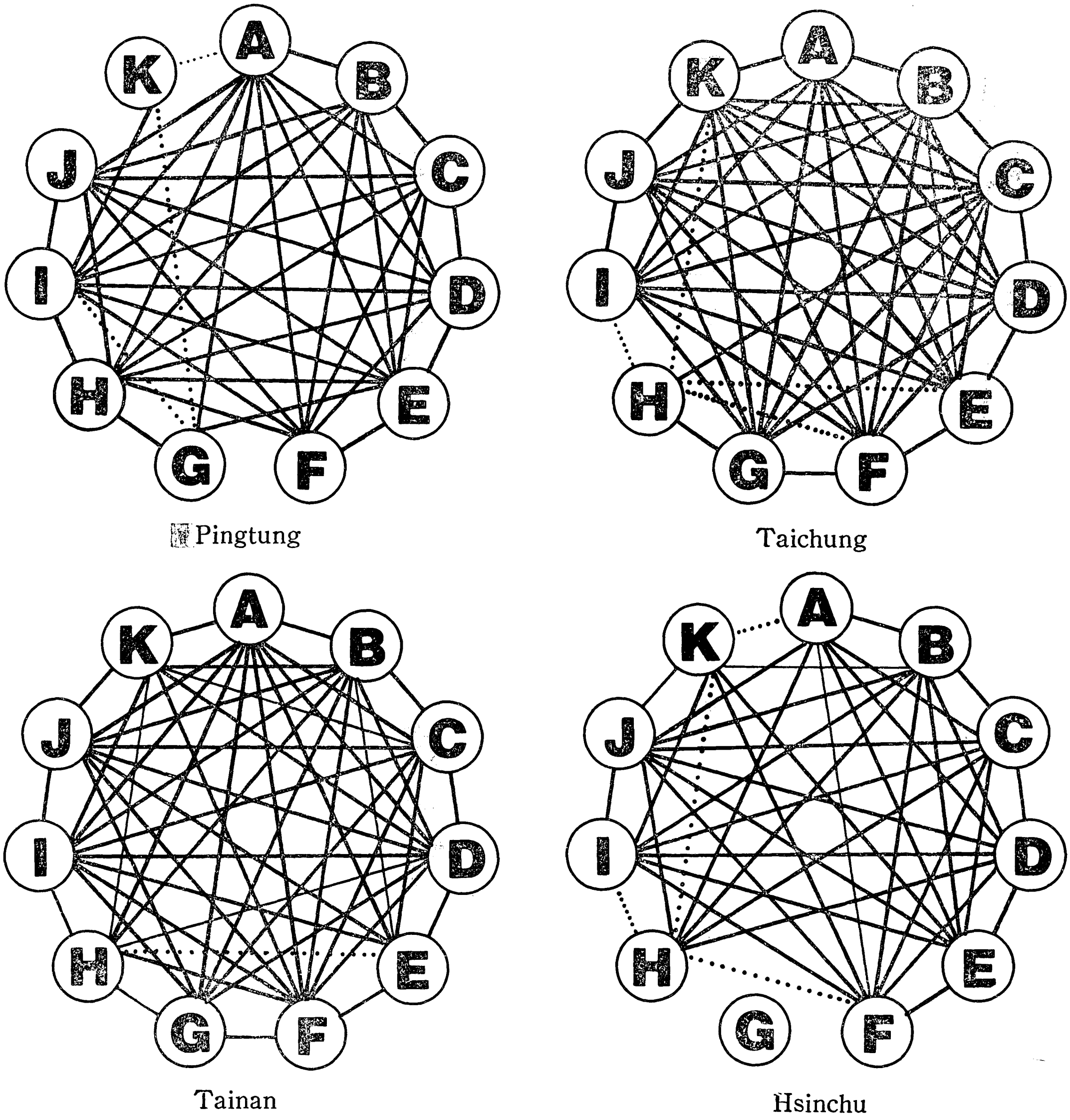

Fig. 1. Schematic diagrams showing the phenotypic correlations between all pairs of 11 agronomic characters for F_2 population of Population A (KS8×TN15) in four locations.

(A) plant height	(G) days (from sowing) to flowering
(B) no. of branches	(H) days (from sowing) to maturity
(C) node number of stem	(I) seed weight/plant
(D) pod number of branches	(J) pod number/plant
(E) pod number of stem	(K) 100-seed weight
(F) seed number/plant	

——— High positive correlation (significant at 1% level)
——— Moderate positive correlation (sig. at 5% level)
••••••• High negative correlation (sig. at 1% level)
··········· Moderate negative correlation (sig. at 5% level)
others with no mark are nonsignificant, either positive or negative.

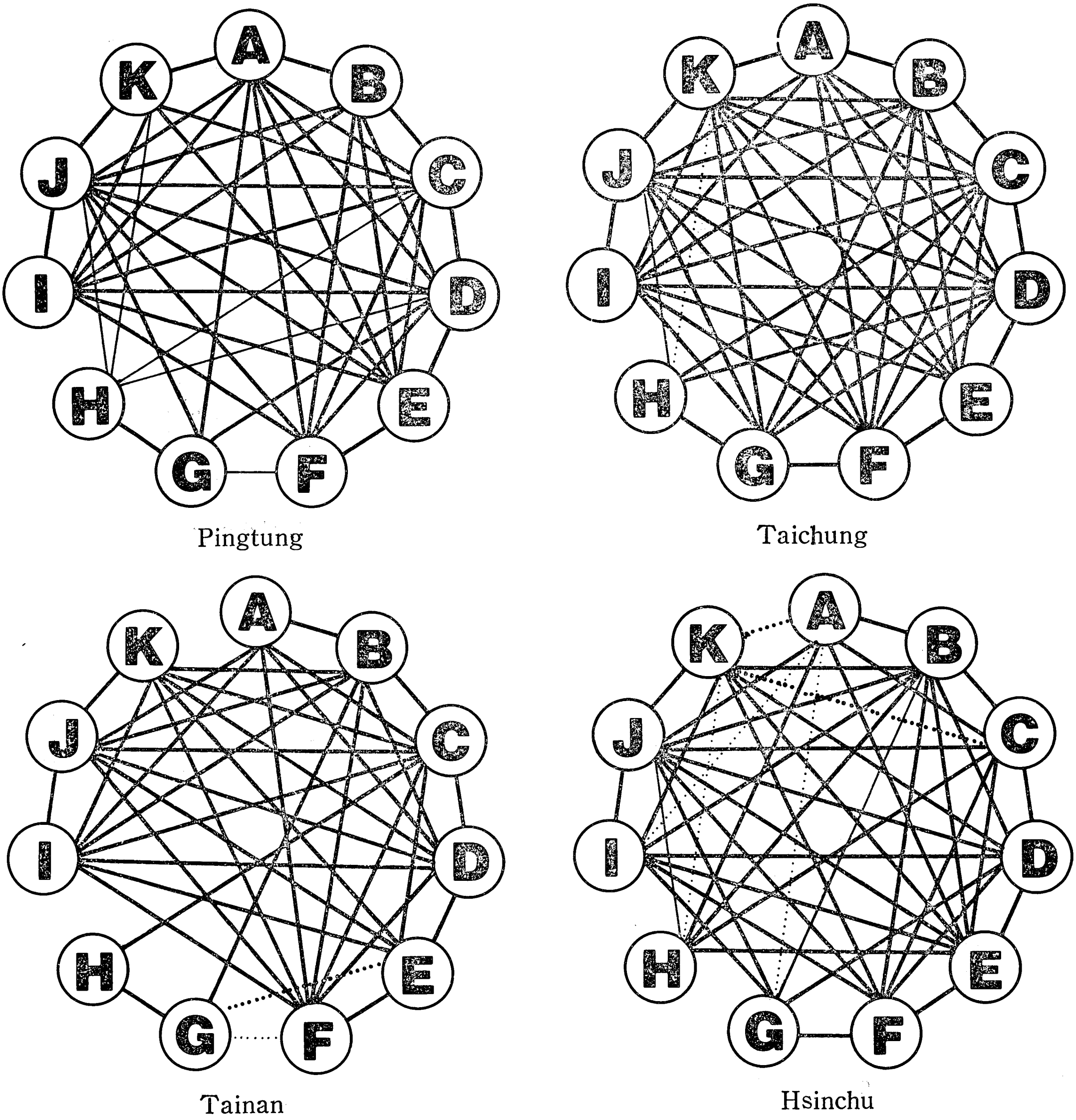

Fig. 2. Schematic diagrams showing the phenotypic correlations between all pairs of 11 agronomic characters for F_2 population of Population B (TN15×T175) in four locations.

(A) plant height	(G) days (from sowing) to flowering
(B) no. of branches	(H) days (from sowing) to maturity
(C) node number of stem	(I) seed weight/plant
(D) pod number of branches	(J) pod number/plant
(E) pod number of stem	(K) 100-seed weight
(F) seed number/plant	

——— High positive correlation (significant at 1% level)

——— Moderate positive correlation (sig. at 5% level)

·······High negative correlation (sig. at 1% level)

············Moderate negative correlation (sig. at 5% level)

others with no mark are nonsignificant, either positive or negative.

In Pingtung location

With the exception of days to flowering and 100-seed weight, the other nine characters such as plant height, branch number, nodes on main stem, pods of branches, pods on main stem, seed number, days to maturity, seed weight, and total pods were significantly positive correlated one another in both populations. In population A, characters between days to flowering and pods on main stem, plant height, and days to maturity were significantly positive correlated, but characters between days to flowering and branch number, nodes on main stem, pods of branches, seed number, and total pods were not associated at all. Further, days to flowering and seed weight, and 100-seed weight were siginificantly negative correlated. In respect to 100-seed weight, it was negatively correlated with plant height, days to flowering, and positively correlated with seed weight, but it was not correlated with other eight characters studied.

In population B, positive correlations were obtained between days to flowering and plant height, pods of branches, seed number, days to maturity, and total pods, but no correlations were found between days to flowering and number of branches, nodes on main stem, pods on main stem, seed weight, and 100-seed weight. Apart from being no correlations between 100-seed weight and number of branches, pods of branches, number of seeds, and days to flowering, positive correlations were found between 100-seed weight with other six characters. As for days to maturity, it had no correlations with plant height, number of branches, pods on main stem, number of seeds, and seed weight, but it had significantly positive correlations with other five characters.

In Tainan location

With the exception of no correlations were found between days to flowering and pods on main stem, 100-seed weight, and between days to maturity and total pods, nodes on main stem, and significant negative correlations found between days to maturity and pods on main stem, the remainder pairs of all characters were positively correlated in population A.

In population B, no correlations were found between pods on main stem and number of branches, plant height, days to maturity, and between dasy to maturity and plant height, number of branches, pods of branches, pods on main stem, number of seeds, seed weight, total pods, and 100-seed weight. As for days to flowering, it was significantly positive correlated with branch number, and days to maturity, and negatively correlated with pods on main stem and seed number, but it was not correlated with other six characters. Except that no correlations were found between 100-seed weight and plant height, days to flowering, and days to maturity, it was significantly positive correlated with other seven characters.

In Taichung location

The following nine characters: plant height, branch number, nodes on main stem,

pods of branches, pods on main stem, number of seeds, days to flowering, seed weight, and total pods were variously positive correlated, and so nine positive correlation groups showed in both populations. However, pairs of characters between days to maturity and pods on main stem, number of seeds, seed weight, and 100-seed weight were negatively correlated, and this character was not correlated with plant height, number of branches, and total pods in population A.

In population B, no correlations were found between days to maturity and plant height, number of branches, pods on main stem, number of seeds, and seed weight; and between days to floweirng and pods on main stem, and plant height. Moreover, significant negative correlation was found between days to maturity and 100-seed weight.

In Hsinchu location

The correlation patterns in Hsinchu location differed greatly from those of other three locations in both populations. In population A, character of days to flowering was independent of other characters. Character pairs between plant height and 100-seed weight, between days to maturity and number of seeds, seed weight, and 100-seed weight were negatively correlated, but the remainants were variously positive correlated.

More negative correlations were found in population B than those in other three locations. They were plant height and days to flowering, seed weight, and 100-seed weight, and 100-seed weight and nodes on main stem, and days to maturity. Character pairs not correlated were plant height and number of seeds, pods of branches; days to flowering and nodes on main stem, pods on main stem, days to maturity, 100-seed weight; days to maturity and pods of branches, number of seeds, seed weight; and seed weight and nodes on main stem. Other pairs of characters, however, were positively correlated, and six of them such as number of branches, nodes on main stem, pods of branches, pods on main stem, number of seeds and total pods were the very correlated groups in population B.

Relationship among Characters

In order to find out the relationship of the eleven characters over four locations, the principal components for each of the phenotypic correlation matrixes were analysed. Their scatter diagrams were shown in Figs. 3 and 4. The figures showed that significant differences of the first and second principal components, mostly existed among locations.

In population A, the scatter diagrams of the three vegetative characters, plant height, branch number, and nodes on main stem resembled with moderate positive component scores either in first or second principal component planes both in Taichung and Hsinchu locations. However, they scattered differently in Tainan and Pingtung locations. Their component scores were moderately positive in first principal component plane, but smaller negative in second principal component plane in Tainan. In Pingtung location, their first principal component scores were moderately positive, but number of branches was positive whereas plant height and nodes on main stem were negative in second principal component plane.

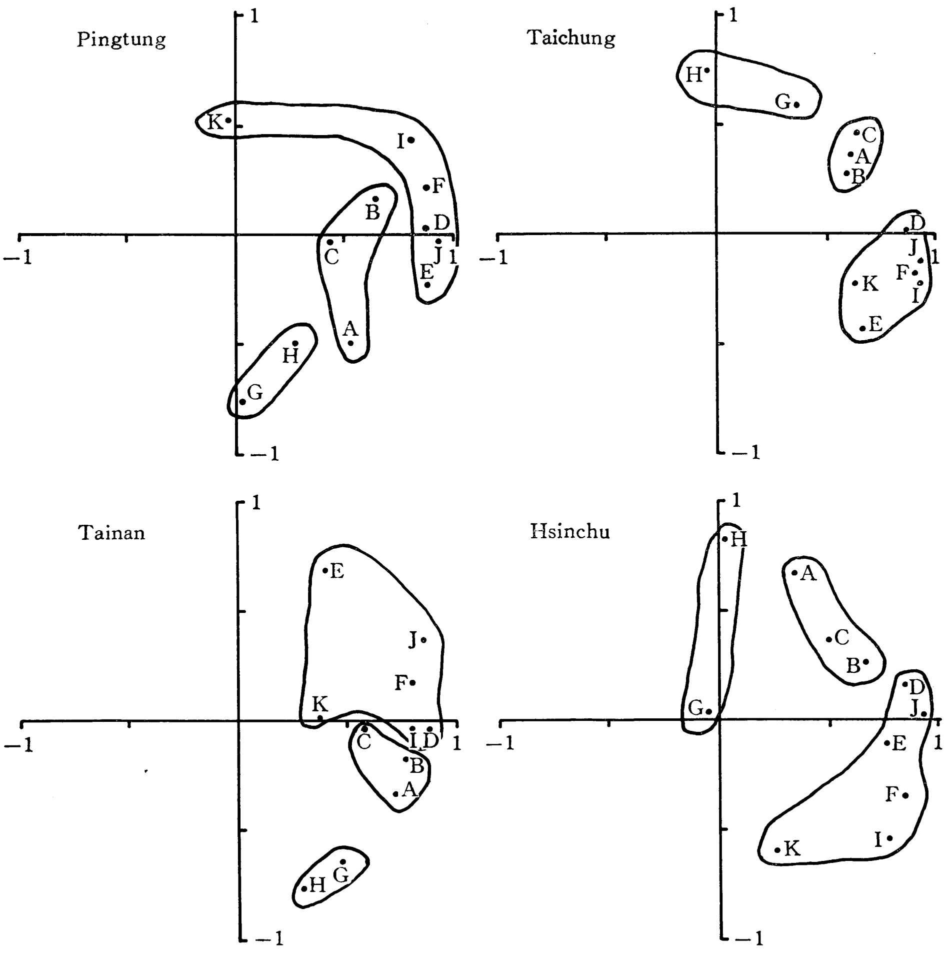

Fig. 3. Eleven characters of population A (KS8×TN15) scattered in the plane defined by the first two components for four locations. Symbols of characters are the same as indicated in Fig. 1.

In population B, the diagrams of the three vegetative characters scattered similarty with positive values both in first and second principal component planes, and they showed close relationship one another in Pingtung and Tainan locations. Close relationship among the three vegetative characters also found in Taichung, but only number of branches and nodes on main stem showed positive scores, while plant height showed negative in second principal component plane. Though the diagrams of the three characters showed positive scores in both principal component planes, they were not closely related one another in Hsinchu location.

As to the characters of days to flowering and maturity, they scattered similarity with positive component scores in first and negative in second principal component plane in population A in Pingtung and Tainan locations. The two characters mentioned had relatively large positive scores in second principal component plane, but days

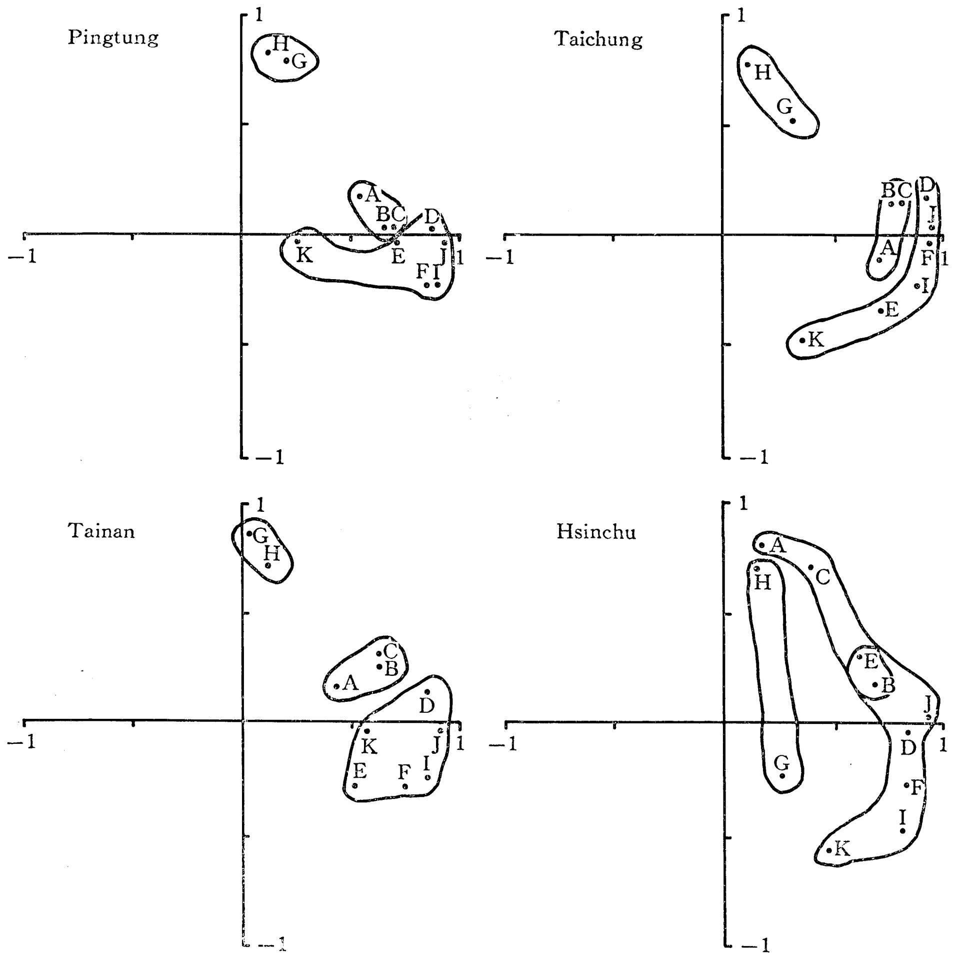

Fig. 4. Eleven characters of population B (TN15×T175) scattered in the plane defined by the first two components for four locations. Symbols of characters are the same as indicated in Fig. 1.

to flowering had large positive score and days to maturity had almost nil in first principal component plane in Taichung. The diagram scores for days to flowering and maturity were almost nil in first and positive large scores in second principal component planes in Hsinchu location. In population B, the scatter diagrams for days to flower ing and maturity showed mostly similar in Pingtung, Tainan and Taichung locations. They had small positive scores in first and large positive scores in second principal component planes. However, the scatter diagram scores for the same two eharacters in Hsinchu differed greatly from those in other three locations. They had small positive score in the first principal component plane, but days to flowering had small negative and days to maturity had large positive score in the second principal component plane.

In respect of the scatter diagrams for yield component characters, such as pods of branches, pods on main stem, number of seeds, total pods, seed weight per plant and

100-seed weight, they differed significantly among four locations.

In population A, their scatter diagrams appeared similar in Taichung and Hsinchu locations, but, they scattered more concentrated and closer in Taichung than those in Hsinchu location. The diagrams for number of seeds, pods of branches, seed weight, and total pods in the first principal component plane resembled in Pingtung and Tainan, while those in the second principal component showed inversely between Tainan and Taichung locations. In population B, the scatter diagrams for yield component characters were closely concentrated in Pingtung, loosely in other three locations. The diagram score for 100-seed weight in the first principal component plane were largely positive in Tainan and Hsinchu locations, moderately in Taichung, and small in Pingtung. On the contrary, in the second principal component plane the component score for 100-seed weight were largely negative in Taichung and Hsinchu locations, but almost nil in Pingtung and Tainan locations. The component score for pods on main stem in the second principal component plane was positively in Hsinchu, approximately nil in Pingtung, and moderately negative in Taichung and Tainan locations.

Discussion

Variation of plant quantitative characters caused by environments or in terms of natural selection were often influenced by the diversity of environment and genetics. In other words, the effect of natural selection depends on the extent of phenotypic and genotypic variation. Generally, heritability indicates the relationship of phenotypic and genotypic variation. Thus, natural selection effect is remarkable and the time needed is shorter on individual plant characters with higher heritability and sensitive to environments. Result in this experiment showed that vegetative characters including plant height, number of branches and days to flowering had higher heritability, and they were greater in norhtern experimental locations than those in southern ones. Hence, significant differences of natural selection effect on hybrid populations among locations may occur when generation added. On the contrary, we found lower heritability values for other yield component characters in this experiment. Since genetic variation is always masked by environmental stress force, less natural selection and less population differentiation would be expected to those with low heritabilities.

In order to survive and propagate the offsprings, the hybrid populations and each individual plants can adapt to a somewhat different range of environmental stimulus resulting from the populational and individual bufferings during the period of growth and development [3]. Researcher [15] also pointed out that the adjustability generated among characters during the course of growth. Distinct differences of the intension and direction of correlations for characters studied were found among locations in this experiment. For instance, closer relationship was found among characters in population A in Tainan and Taichung, and in population B in Taichung and Hsinchu locations. These result suggest that differentiation occured in F_2 populations grown in four loctions.

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The authors wish to express their sincere appreciation to Taoyuan and Kaohsiung District Agricultural Improvement Stations for giving us assistance to carry out this work, and to Dr. Shiu-cho Woo of Institute of Botany, Academic Sinica, for the reading and rectifying of this typescript.

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春作單向及不同栽培地區之自然淘汰對大豆雜種集團育種行為之影響[1]

II. F_2 世代農藝性狀遺傳率及相關之變異

詹國連　李瑞興　曾富生[2]

摘　要

使用 KS8×TN15 (A 集團) 及 TN15×T175 (B 集團) 兩個大豆雜種集團之 F_2 種子，於1983年春作分別播種於臺灣四個地區，探討 F_2 集團在四個不同栽培環境下，農藝性狀之遺傳率及相關之變異。試驗結果顯示，一般營養性狀之遺傳率較高，產量構成性狀較低。而遺傳率之大小因栽培地區之不同，有顯著差異。營養性狀之遺傳率且呈南向北增大之趨勢。性狀間相關之強弱及方向，在地區間均有明顯差異；一般 A 集團之性狀在臺中及臺南，B 集團之性狀在臺中及新竹較其他地區密切。由此等地區間性狀遺傳率及相關之變異現象，可推測本試驗之F_2雜種集團，已有地區間分化現象。

1.臺灣省農業試驗所　研究報告第 1287 號。

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中華農業研究（Jour. Agric. Res. China）35（3）：292～299（1986）

不同環境對山葵生長與產量之影響[1]

胡 敏 夫　邱 善 美　劉 新 裕[2]

摘要：爲了探討山葵之適應性與新地區栽培對墨入病（*Phoma wasabia* YOKOGI）蔓延之遏阻程度，乃選定本省中部海拔1200M高冷地信義與溪頭兩地方，分別採用人工架設黑色塑膠網與不同自然環境試作發現：1.信義試區：所種植山葵之生育，以架設75～80%遮蔭網較佳，種植後90天之平均株高爲 16.9cm，平均葉數爲17.8葉。經測定其實際遮蔭率恰爲70%，適合山葵之生長，惟其後因栽培環境溫度偏高、濕度偏低，並發生白銹病，而於成熟前乾枯死亡，因之信義地區可能較不適合種植山葵。2.溪頭試區：發現種植於空曠地山葵之生育較杉樹下良好，平均公頃根莖量爲17,125kg，葉柄量爲 26,750kg，鬚根量爲5,625kg。平均公頃估計收入可達3,596,250元，比杉樹下種植區多收1,396,250元。於溪頭試區就氣溫因子加以調查，發現溪頭試作區栽培環境可媲美阿里山產區，也比日本伊豆產區優異，且產量高於日本伊豆地區。墨入病罹病率調查結果，空曠地區者達100%，根莖平均罹病長度爲5.2cm，杉樹下試區罹病率爲80%，根莖平均罹病長度 4.2cm，經研判其因可能爲種苗帶菌所引起。

山葵（*Wasabia japonica* (Miquel) Matsum）爲一十字花科之多年生草本植物，喜陰濕又耐寒，通常爲野生或被栽培於高冷地之杉木下。其全株均具有獨特風味，以香、辛、甘及粘等4種特色傲居所有香辛料作物之上，更非人工代替物芥茉粉所能比擬。其成分及藥效據邱氏報告[2]，含配醣體（Sinigrin），酵素（Amylase, Invertase, Lipase, Peroxydase, Tyrosinase、Esterose）、Allylisothiocyanate, Butylisothiocyanate及 Vitamin C等，有促進食慾、防腐、殺菌之效，並有解魚毒、發汗、利尿及淸血等功用，因之日人常作爲吃生魚片之佐料。

我國大陸多處省份均有栽培山葵。日本產區則分佈於靜岡縣、長野縣、島根縣、鳥取縣、東京都及山梨縣等地，全國栽培面積計600ha[7]。本省山葵栽培始於民國3年，由日人佐藤昌氏自日本宮城縣引進於阿里山試種成功，訖今已數十年歷史，惟因栽培土地取得不易，農民於同一土地上久年栽培，遭受墨入病（*Phoma wasabia* YOKOGI）嚴重侵害蔓延，其罹病率高達70%[4]，農民損失甚鉅。本所有鑑於此，特計劃於本省中部高冷地區選擇適當地點試作，以探討山葵之適應性與新地區栽培山葵對墨入病蔓延之遏阻程度，作爲將來擴大栽培面積之參考，經二年調查結果報告如下。

材料與方法

供試作之山葵品種係原由日人早期引進於阿里山種植之青莖品種一種，供試地點選定南投縣境內之信義鄉草坪頂與鹿谷鄉溪頭二處進行，海拔高度二處均爲 1,200m左右。草坪頂試作區爲一般種植茶樹之台地，周圍無樹林遮蔭需採用人工遮蔭式栽培，遮光率採用25—30%，35—40%，55—60%及75—80%等4級之黑色遮光網架設，試驗設計採逢機完全區集設計，4重複，小區面積 60m^2，試作

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面積計 1,000m²。溪頭試作區則以杉樹下與空曠地區（周圍有廣大杉樹林）二處理進行，試驗設計亦採逢機完全區集設計，4重複，小區面積各爲 125m²，試作面積計1,000m²。種植前土地先開墾，將石頭及枯枝移開，然後每 0.1ha 施用石灰 120kg精細碎土混合，草坪頂試區則每 0.1ha加施用堆肥1,000kg，兩處均作成寬面高畦之畦式種植，種苗採用 1000倍樸拉克稀釋液消毒1小時，行株距採20×20cm，種植日期爲73年4月3日，植後60天行第一次追肥，追肥量爲複合肥料1號 0.1ha 40kg，第二次追肥於9月間施用，施用量同第一次；第二年於4月間施第三次追肥，追肥量爲 0.1ha20kg，生育期間於每屆溫度回升時適時噴施萬力 1,000倍，以防治病害發生，其餘栽培管理方法，仿效一般慣行方法行之(3,5)。調查項目爲株高、分蘖數、葉數、罹病率、主根長度、根莖及地上部各部份重量等。株高及分蘖數之調查係於生育期間每隔60天行之，其餘均於收穫時調查之，調查株數各處理爲20株。

結果與討論

一、信義鄉草坪頂試作區

此試作區採用人工遮蔭式栽培，各試區之山葵初期生育均良好，25～30%遮光區種植60天後其平均株高爲8.1cm，平均葉數爲 5.3葉，35～40%爲9.2cm，5.6葉，55～60%爲9.4cm，5.6葉，75～80%爲 14.1cm，6.5葉。種植後120天調查其平均株高及葉數依序爲 6,1cm，3.2葉，11.6cm 10.8葉，6.9cm5.2葉及16.9cm，17.8葉。從此調查結果顯示，發現採用75～80%遮光網栽培區之山葵生育最好，而25～30%遮光區生育最差，此後因適值夏季該地區溫度驟然升高，以致所有試區之山葵均發生嚴重白誘病，雖於發生初期噴佈萬力可濕粉劑防治但仍無法遏阻其蔓延，最後均全部萎凋乾枯死亡。

二、鹿谷鄉溪頭試作區

溪頭試區天然環境較良好，雖海拔僅 1,200m左右，但附近有廣大杉林生長，栽培環境較略似阿里山產地，且水源豐富適合山葵生長，惟僅選擇杉樹下種植非爲將來擴大山葵栽培面積之途；因之另選擇空曠坡地而附近周圍有杉樹林種植爲對照，經收穫調查結果如表1及2。

從表1數據顯示，空曠地試區之山葵生育比杉樹下試區良好，平均株高達 30cm比後者高4.3cm，平均分蘖數亦多5支，葉數與全株重幾乎爲杉樹下試區之2倍。另從植株各部重量及百分率探討，發現二處理區之山葵植株地上部重及百分率均很高，而根莖重及百分率均較低，依據日人横木氏的報告(7)，山葵平均單株重量 122g，其根莖重 43.8g佔全株重百分率爲35.9%，由此可知本省所種植山

表1. 不同處理區山葵之農藝特性表現

Table 1. Agronomic performance of wasabia plants grown under different environments at Hsitou area.

Treatment	Plant ht. (cm)	Tillers	No. of leaves/plant	Whole plant wt. (g)	Each part wt. of a wasabia plant (g)			
					Leaf	Petiole	Rhizome	Rootlets
Under conifer trees	25.7	9	36.5	164	63.8 (39%)	51.2 (31.2%)	43 (26.2%)	6 (3.6%)
Open area	30	14.2	70.2	306.8	108.8 (35.5%)	107 (34.9%)	68.5 (21.3%)	22.5 (7.3%)

*: Number in parentheses indicate percentage each part of a wasabia plant.

表2. 不同處理區山葵之產量

Table 2. Comparison of different environments on the yield of wasabia and disease incidence by *Phoma wasabia* at Hsitou area.

Treatment	Main rhizome		Lesion length (cm)	Infection by *phoma wasabia* (%)	Yield (kg/ha)		
	Length (cm)	Diameter (cm)			Petiole	Rhizome	Rootlets
Under conifer trees	7.6	1.98	4.2	80	12,800	10,750	1,500
Open area	8.73	2.43	5.2	100	26,750	17,125	5,625

葵之根莖重量確實不比日本所生產低，惟地上部太繁茂佔全株重之百分率太高，此對以收穫根莖爲目的之作物非爲良好現象，今後從事山葵栽培技術改良上應當特別注重此問題。

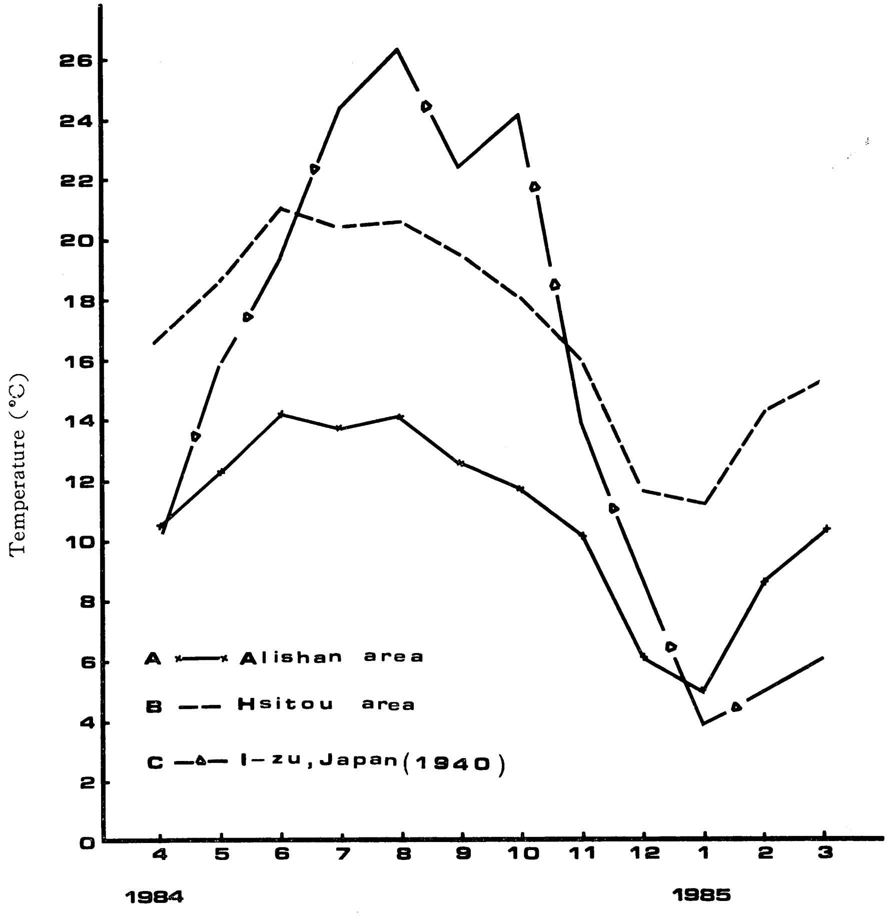

圖1. 溪頭試區與阿里山及日本伊豆產地氣溫變化之比較。

Fig. 1. Comparison of air temperature at Hsitou and Alishan, Taiwan, and I-zu, Japan.

山葵雖全株各部具辛味可供調味品，但本省加工廠未設立前主產品均以根莖爲主，一般民間商人均於秋冬之際前往阿里山產地購買無病害之新鮮山葵根莖，以飛機直運日本批賣，收購價格每公斤約380～400元之間，於日本市場批發價格1公斤約新臺幣800～1,000元左右。直至近年因本省阿里山產地之山葵墨入病猖獗，可出售之鮮山葵根莖量少，商人乃設立工廠加工成山葵漬物出售，因此感染墨入病之根莖始被商人連同原被遺棄之葉柄及鬚根一起收購加工，通常於產地收購價格葉柄1公斤15元，鬚根1公斤20元，有罹病之根莖爲 180元，此舉使栽培農戶獲益不少，因之山葵產量調查除根莖外，葉柄及鬚根重量有必要調查。表2資料顯示，空曠地試區山葵根莖產量比杉樹下試區每公頃高59%，葉柄產量高109%，鬚根產量爲275%，此很明顯發覺杉樹下試區之環境，因日照不足導致使山葵生育受阻。據橫木氏報告[7]，山葵生長之最適遮蔭率爲60～70%，溪頭試區據筆者於73年6月27日中午10時40分使用測光計測定結果，空曠地試區當時光度爲3.5×10^3 microensterins $m^2/sec.$，杉樹下試區爲 0.55×10^3 microensterins $m^2/sec.$，其照光量恰爲前者15.7%，即其遮光率達84.3%，顯然比其適合生長之蔭遮率60～70%高，因之溪頭地方利用杉樹林下種植山葵應當疏木或修剪樹木枝條加以調整遮蔭率。

就產品價值而言，若以前述收購價格估算產值則杉樹下試區每公頃粗收入爲 2,200,000（其中根莖20%量以每公斤 380元計算）空曠地試區爲3,596,250 元，兩試區粗收入比較，則後者多收 1,396,250元，若能有效防治墨入病則根莖價格以每公斤 380元計算，其公頃粗收入當達千萬元以上。其次再就墨入病罹病程度調查，發現杉樹下試區之山葵根莖平均受害長度爲4.2cm，罹病率爲80%，其罹病長度變異量爲0～8cm，但空曠地試區則爲5.2cm，100%，罹病長度變異量爲 1～8cm，雖然空曠地試區之山葵植株生育較杉樹下好，但均全部罹病此可能因種苗帶菌外，日照量較充足而導致氣溫升高有利於病菌生長所致。

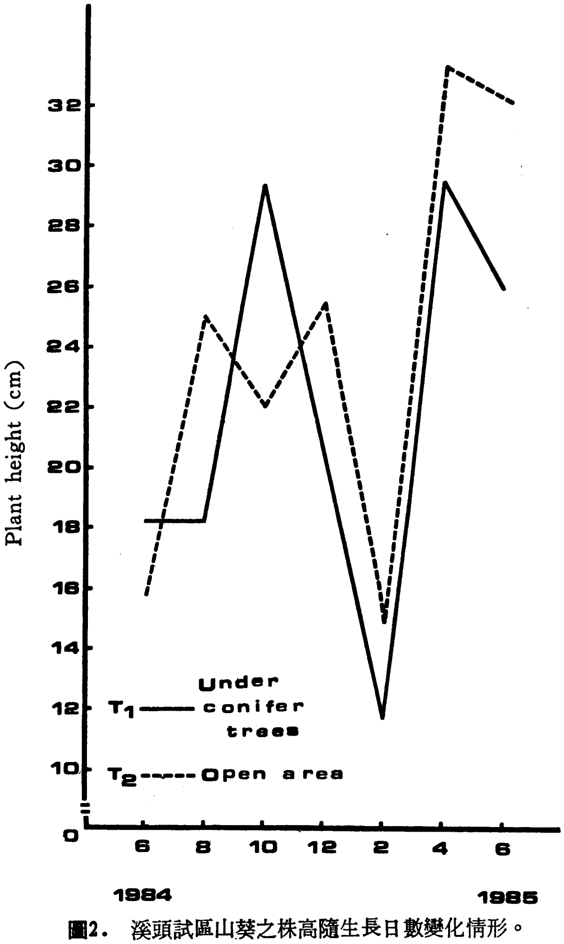

圖2. 溪頭試區山葵之株高隨生長日數變化情形。

Fig. 2. Plant height of wasabia grown at Hsitou

三、栽培環境之探討

1.氣溫變化對山葵生育之影響：

山葵性喜陰涼多濕環境下生長、生育溫度約爲 8～20°C，但最適生育溫度爲 15～18°C[3,7]，一般栽培場所選定以夏季氣溫爲基準，夏季氣溫平均超過 23°C時則不適宜栽培，反之冬季氣溫在零下 3°C時山葵易受寒害，依據中央氣象局所作報導[1]。本省阿里山 1984—1985氣溫調查（A），發現於6月份最高氣溫才14°C 左右（如圖1）最低氣溫於1985年1月時出現約5°C左右，於此溫度範圍確實很適合山葵生長。其次就溪頭試作區之氣溫（B）探討，亦發現氣溫高於 20°C 之時間僅1984年之6－8月間，其中最高氣溫爲 22°C 左右亦未達 23°C 以上，由此可知溪頭試作區亦頗適合山葵生長。另據日人宮清林造[6]，1940年

圖3. 溪頭杉樹下試區山葵生育情形

Fig. 3. The plants of wasabia grown under conifer trees at Hsitou.

圖4. 溪頭空曠地試區山葵生育情形

Fig. 4. The plants of wasabia wasabia grown in the open area at Hsitou.

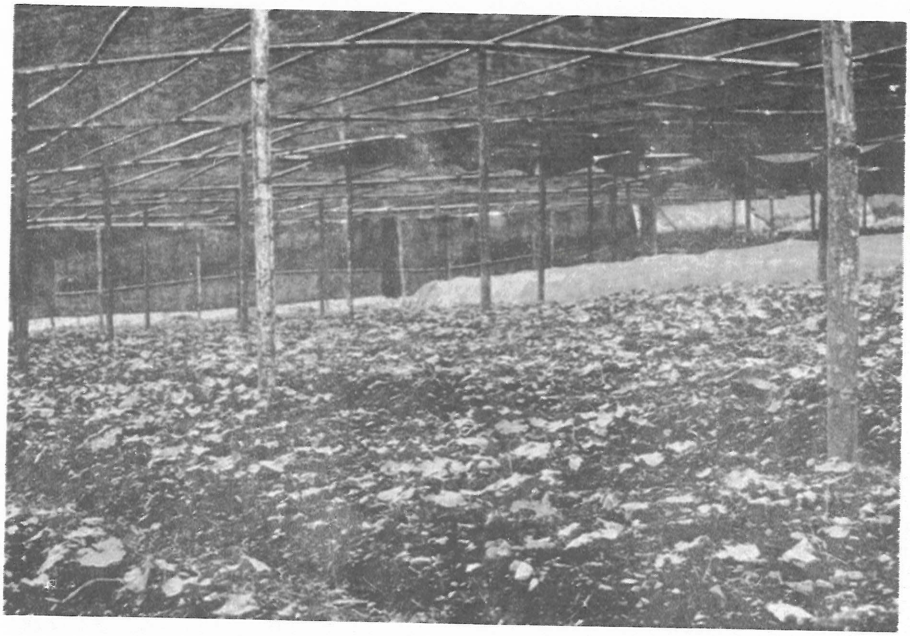

圖5. 信義鄉草坪頂人工遮蔭下山葵生育情形
Fig. 5. The plants of wasabia grown under black polyethylene nets at Hsinyi.

伊豆山葵產區之氣溫調查（C），發現從7月份至11月份間氣溫均超過 23°C，其中以8月的氣溫最高達 26°C 左右，即不適宜山葵生長之高氣溫時間達4個多月，因之若以日本山葵主產區之一伊豆地方與本省阿里山及溪頭比較，本省栽山葵之溫度環境比日本佳。

氣溫影響山葵生育情形可從溪頭試作區之山葵株高調查可知（如圖2），杉樹下試區（T_1）種植之山葵生育較好之時期發現第一年於9月—11月份間，第三年則於3月—5月間，此時間正值於多季與春季時間，其氣溫均值於16—19°C之間，而生育最差時間爲12月—2月份間，株高僅 12cm左右，此時氣溫較低，山葵地上部萎凋僅留心葉，生育停滯。空曠地試區（T_2）山葵之生育則發現種植初期生長較（T_1）區快，然至夏季期間因氣溫升高生育受阻直至秋季時再逐漸恢復生長，但仍然於12月—2月份受低氣溫影響生長亦停滯，至第二年春天則生育較T_1區良好株高達 32cm以上，由上述探討結果T_1區（如圖3）應適當疏木或修剪樹木枝條增加日照量以促進山葵初期生育，而 T_2區（如圖4）則於夏季期間應輔以適當人工遮蔭以防日光直接照射而影響山葵生育。

2.採用人工遮蔭栽培山葵之可行性探討：信義鄉草坪頂爲一新興茶區，原種植於四周之杉樹林均砍伐殆盡，以致中午時刻顯得有炎熱之感，然若欲尋覓國有林下種植山葵，則土地取得十分困難。最後試以架設人工遮蔭網探討其可栽培山葵之可行性。乃選擇市面上出售之25—30%，35—40%，55—60%及75—80%等4種規格之黑色遮光網架設，並於73年6月12日下午1時測定當地自然環境日照光度爲 11.4×10^3 microensterins M^2/sec.；25～30% 遮光網爲 5.2×10^3 microensterins M^2/sec.；55～60%遮光網爲 4.4×10^3 microensterins M^2/sec.；75～85%遮光網爲 3.4×10^3 microensterins M^2/sec.；實際遮光率經換算依次爲48%、55%、62%及70%，即以架設75—80%黑色遮光網之遮光率最符合山葵生長遮光率之需求，因之此試區山葵生長亦較好，然於精耕之臺地而四周無廣大杉樹林被覆，採用75—80%遮光網架設栽培山葵，雖輔以人工開溝灌漑及噴霧設施，其濕度及微氣候仍不如天然環境之狀況下，栽培山葵亦不能成功（詳如圖5）。

結　　論

綜觀上述試驗結果，山葵在本省栽培於環境上而言，確實較日本優異且產量高，於經濟價值而言，其每公頃估計收入達3百萬元以上，爲目前各種作物所不能及，因之早期確定山葵生產政策及着重加强山葵品品種選育與栽培技術上改良並派遣技術人員前往日本研習山葵栽培技術是目前不可延緩之工作。惟可栽培山葵之土地均爲政府所管轄，農民不易取得，將來本省山葵栽培事業之發展將受到限制。利用臺地架設人工遮蔭網栽培山葵應當選擇周圍有廣大杉樹林之北向或東北向並有豐富水源地方栽培始可，否則應當有計畫栽培果樹待成林後再輔以適當人工遮蔭栽培。至於墨入病防治研究，有關當局應當籲請從事植病研究人員同心協力加强研究防治對策，以杜絕此病害蔓延而增加鮮山葵生產，綿延外銷日本市場貨源增加國家外匯收入。

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Effect of Different Environment on the Growth and Yield of *Wasabia Japonica* (Miquel) Matsum[1]

M. F. Hu, S. M. Chiu and S. Y. Liu[2]

Summary

In order to find out some new places suitable for the growth of wasabia and to minimize the severe damage caused by *phoma* blight disease, experiments were conducted at Hsinyi and Hsitou areas, both are 1200m above sea level and in Nantou county.

For lack of natural shading, the Hsinyi plots were shaded with black polyethylene nets which can reduce different amount of light intensity. The results in Hsinyi area indicated that the light intensity of the treatment with 75—80% shading net, which reduced 70% of the light, was favorable to the growth of wasabia. The mean number of leaves per plant and plant height were 17.8 leaves and 16.9cm at the 90th day after planting, However, the plants were possibly killed by high temperature, low humidity, and the infection of white rust disease during the maturity time. Therefore, Hsinyi area was not suitable for the growth of wasabia.

On the other hand, the plants of Hsitou plots were grown in the conifer forest either under the conifer trees with natural shading or in the open area without shading. The results of the open area at Hsitou were more favorable for the growth of wasabia, when compared to those under conifer trees in the same area. Alishan area in Chiayi and I-zu Japan. The production of main rhizome, petiole, and rootlets were 17,125 kg/ha, 26,750 kg/ha, and 5,625 kg/ha, respectively. The total income reached about 3,596,250 NT$ /ha, which was 1,396,250 dollers more than that under the conifer trees. However, the severity of infection of *phoma* blight fungus were not reduced. In the open area all rhizomes were infected and the lesion length was recorded 5.2 cm/rhizom. The correspondent values of the plants grown under the conifers were 80% and 4.2 cm/rhizom. The reasons caused the high infection rate might be due to the seedings which were fungus-carrier and could not be easily detected before planting and lack of suitable method for disease countrol. Therefore, preparing of healthy seedings and some useful methods of disease control become important for a profitable cultivation of wasabia in Hsitou area.

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中華農業研究（Jour. Agric. Res. China）35（3）：300～307（1986）

馬鈴薯之品種比較試驗[1]

曹幸之[2]

摘要：爲選出新的馬鈴薯品種，以供應新近在本省發展的加工食品消費市場，以目前栽培品種爲對照，進行品種（系）試驗，調查它們的產量，薯球特性與比重。19個供試品種爲根據過去的觀察結果，或爲栽培容易且不易罹毒素病的品種，或爲已知其乾物含量高的品種。

生長後期的連續陰雨嚴重影響各品種的乾物含量，薯球的比重數值均低，除 No. 732 達1.071外，其餘均介於1.039至1.060。就產量而言，Hudson 最高，每公頃42公噸， Russet Burbank則生產薯球最小，產量最低，21t/ha

Omega 爲歐洲黃皮黃肉小薯品種，很適宜東南亞市場需要，另外在沒有選出新加工品種前，調查產地 Kennebec 的乾物量，發現薯球比重均在1.078以上，合乾物量20.3%以上，合乎加工需要。

本省所栽培的馬鈴薯以「五峰」、「克難」與「卡第娜」三種爲主，過去一直當成蔬菜食用，鮮銷國內或國外市場，由於時代變遷，社會繁榮，速食店因應而出，民國73年初美國麥當勞食品公司首在臺北成立第一家連鎖店，每天需消費 750公斤的馬鈴薯製成炸薯條，不僅增加馬鈴薯的消耗，也使本省開始重視馬鈴薯的加工品質。除了麥當勞計劃在本省共成立10家連鎖店外，美國喜互惠、溫蒂漢堡、肯塔基炸雞食品店也於今年在臺北相繼開張，供應冷凍薯條、薯泥與薯片。

在美國，馬鈴薯依其外表、品種分成四類，其中圓白型最多，黃褐粗皮型栽培面積最廣，其他二類爲長白型、與紅皮型；依消費型式，鮮食佔46%，餘爲加工食品（冷凍食品28%，薯片13%，脫水食品８%，近年更發展一種炸薯皮）(11)，不論鮮食或加工，其食用質地（texture）與薯球所含的乾物量、比重成正相關(7,8,12)，好吃的馬鈴薯要吃起來粉粉鬆鬆的（mealy），而這粉粉鬆鬆的程度決定於薯球內固形物的含量，做薯條或薯片的馬鈴薯必須具有20%以上的乾物含量，即比重要在 1.077以上，還原糖要不超過0.5%，才能由單位鮮重獲得品質好又最高產量的加工品，比重每增加0.005，則每45公斤（100磅）去皮鮮馬鈴薯，可多製出１磅的炸薯片(12)。

世界各國中，美國對馬鈴薯的加工食品最爲推廣普遍，因此本所近年向美國引進一些品種，觀察它們在本省栽培條件下的適應性，期能選出豐產又高乾物含量的品種，提供農民種植，以配合市場的需要。另外，「克難」品種在本省已栽培多年，它是美國的第二大品種，主要加工做成薯片(11,12)，也是很好的鮮食品種，因此，到產地取樣其薯球，調查乾物含量是否合乎加工需要。

材料與方法

1.材　料：

品種試驗所用材料包括19個品種（系），另以２個本省栽培品種做爲對照。「克難」與「卡第娜」（均爲對照品種）種薯購自豐原農會，其餘品種（系）則爲農試所自留種，種植時種薯都已發芽，

1.臺灣省農業試驗所　研究報告第 1289 號。本研究之經費承行政院農業發展委員會補助，謹此誌謝。
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各品種（系）的來源列於表1。

表 1. 供試馬鈴薯品種（系）的來源與特性

Table 1. Source and tuber type of tested potato varieties

品種（系）(Line)	來源 (Source)	農試所試驗田繁殖代數 (No. of generation in field TARI)	特性 (Tuber type)
No. 30	亞蔬中心（AVRDC)	5	圓白型、大小、形狀均齊
No. 125	AVRDC	5	圓白大薯
No. 386	AVRDC	5	黃皮長圓型
No. 410	AVRDC	5	淡黃圓型
No. 455	AVRDC	5	黃白圓型、整齊
No. 632	AVRDC	5	淺黃、圓型大薯
No. 724	AVRDC	5	黃皮、整齊
No. 732	AVRDC	5	粉紅皮、乾物含量高
No. 770	AVRDC	5	略長型
No. 772	AVRDC	5	圓白型
72008	馬鈴薯中心（CIP)	1	長白型 CIP 品種
800301	CIP	1	圓白型帶淺紅芽眼 CIP 品種
LT-2	CIP	1	黃色中薯 CIP 品種
Atzimba	CIP	2	薯大、圓白型、墨西哥種
Red pontiac	CIP	1	紅皮大圓型、芽眼中等
Russet Burbank	CIP	1	長形、黃褐粗皮、最宜製薯條、烤食
Omega	桃園區農改場	4	黃皮黃肉、略長形、歐洲種
Atlantic	美國農部 USDA	2	圓白型、芽眼淺、比重高、極宜製薯片
Hudson	U. S. D. A	2	薯大、圓白型

2.品種（系）比較：

各品種（系）的種薯未經切薯於民國73年11月13日完全逢機種於農試所試驗田，各品種（系）重覆2－4次不等，小區面積1.2×3平方公尺，採雙行植，每小區20穴，整地作畦前撒施牛糞720公斤／公畝，畦面施化學肥料，一公畝 N：8.4公斤， P_2O_5 ：14.4公斤，K_2O：12公斤，於種植後覆土時掩入，生長期中培土兩次，培土前均施加追肥，每隔7—10天行畦溝灌溉，與噴施農藥。

種植後1—1½個月，拔除由種薯帶病之毒素病株。由於自 74年2月初連續陰雨不止，所有品種均同於2月25日採收，先經數天風乾、剝除附在薯球的泥土後，秤重，並以 Rydmometer [8] 測其比重。

3.產地「克難」薯球之乾物量調查：

自民國74年1月起陸續到產地徵得農戶同意，以每田區2－3個取樣，將當天採收的薯球帶回農試所，測其比重，以平均值表示。各田區的「克難」生育日數85至97天不等，因2月開始陰雨而中止取樣調查。

結　　果

1.試驗期間的溫度與雨水，如表2所示，11月下旬的最高氣溫爲 27°C ，逐漸下降到12月下旬約爲 22°C ，再由1月回升到 23—24°C，最低氣溫由11月下旬的 14°C 漸降至1月爲 11°C ，到2月再回升爲 14°C ，但2月開始的連續陰雨，不僅使溫度降低，也使日照減少，而土壤也一直在潮濕的情況。

表 2. 試驗期間的溫度與雨水[a]

Table 2. *Meteorological data during the experinental* period at TARI, 1984—1985

日期	氣溫 °C			雨水		相對濕度 %	日照 (小時)
	最高	最低	平均	mm	日數[b]		
11月 1—15	29.9	17.3	23.6	0	0	80.0	7.2
11月 16—30	26.8	14.1	20.5	0	0	76.9	4.9
12月 1—15	26.9	11.4	19.1	5.9	1	75.7	5.6
12月 16—31	22.1	11.1	16.6	0	0	78.4	4.2
1月 1—15	23.2	11.6	17.4	3.1	1	76.7	5.3
1月 16—31	24.0	10.6	17.3	21.6	2	77.4	6.8
2月 1—15	22.7	14.1	18.4	251.8	8	84.8	3.3
2月 16—28	20.9	13.6	17.2	65.3	7	87.5	3.4

a. 農試所氣象站資料
b. 雨水 2mm 的天數

2.各品種於種植後20天時均已完全出芽，但有些種薯帶有病毒，常見的病徵有縺葉、嵌紋，較少葉脈壞疽與捲葉，如表3所示，各品種帶病率不同，其中 atlantic、Hudson 最高，達 50%以上，次於 Atzimba 也有40%以上，顯示這些品種易罹毒素病，尤其本省毒素病多呈複合感染，田間留種不易。 Red pontiac、Russet、Burbank 原對多種病害均呈罹病性 [12]，本試驗中帶病率甚低或無，係因一年前才引進，在本所田間僅種植觀察一次，同時引進的 720088、800301、LT-2發病率亦低。品系 No. 386、770 與772 均在本所連續種植5年，多年觀察結果，顯示比其他品系耐毒素病，上季留種的帶病率爲零（目測），其他 No. 125、455、724 等品系因毒素病拔除的比率亦低，栽培品種「克難」與「卡第娜」的帶病率分別爲18.3%與22.5%。

就產量而言，產量最高爲 Hudson, 42t/ha 平均每株1.01公斤，最低爲 Russet Burbank, 21 t/ha 單株爲 0.5kg ，對照品種「克難」爲 24t/ha 卡第娜 34t/ha 。其中共有 Atzimba 等10個品種產量達 30t/ha 以上，但就薯球大小而言，只有 Hudson No. 125, 410, 632, 770 與800301 6個品種達到卡第娜與克難兩品種的平均薯重，而 Omega 與 LT-2 的平均薯球爲 100公克，屬小薯品種，Russet Burbank 薯球平均爲75公克，最小。薯球比重最高只有 No. 732 的 1.071，合乾物含量18.8%，其次爲 Russet Burbank 與 No. 386，比重爲1.060，Atlantic 1.058，最低爲 No. 30 的1.039，卡第娜1.054、克難1.056，比過去所測之卡第娜1.081及克難1.071（1984年記錄）低甚多，當係受生育後期連續雨水的影響。

3.在豐原、潭子等產地，九、十月間的日間最高氣溫達 30°C 以上，但夜間氣溫降至 20°C，此

表 3. 馬鈴薯之品種（系）比較[a]

Table 3. Results of potatos yield and specific gravity in evaluation trial

品種	健株率 %	薯球產量 g/pl	t/ha[b]	指數 %	平均薯球大小指數 %	比重
Atlantic	42.5	625	26	91	92	1.058
Atzimba	58.8	791	33	115	93	1.044
Hudson	45.0	1,010	42	147	125	1.047
Omega	88.8	603	25	88	74	1.054
Red Pontiac	97.5	678	28	99	86	1.045
Russet Burbank	100.0	507	21	74	59	1.060
No. 30	80.0	734	31	107	80	1.039
No. 125	93.3	700	29	102	108	1.041
No. 386	100.0	786	33	114	82	1.060
No. 410	81.7	850	36	124	103	1.050
No. 455	95.0	553	23	81	78	1.046
No. 632	88.3	797	33	116	104	1.048
No. 724	91.7	761	32	111	90	1.040
No. 732	82.5	848	36	123	82	1.071
No. 770	100.0	659	28	96	79	1.052
No. 772	100.0	672	28	98	99	1.046
LT-2	96.7	574	24	84	78	1.045
720088	100.0	668	30	97	81	1.041
800301	90.0	790	33	115	99	1.048
對照品種（克難十卡第娜平均）	80.0	687	29	100	100	1.056

a. 各品種以２—４個重覆，完全逢機種植，小區面積1.2×３平方公尺，20株
種植日期：73年11月13日　採收日期：74年２月25日

b. 以每公頃42,000株計

期間種植的克難種，於一月陸續採收，由不同農戶處取樣的薯球，其比重均在 1,078以上（表４），含乾物量20.3%以上。

討　論

由種薯的發芽、出土，地上部莖葉的生長，到地下薯球的生長，馬鈴薯的產量決定於每日的生產量與生育日數 (Yield = production per day × number of days)[2,3]，氣候條件如光照、溫度與栽培條件如種植密度，種薯生理年齡 (physiological age)、氮肥、水分、病蟲害防治等，不僅影響植株的光合，呼吸作用與生育期長短，而且也影響碳水化合物在莖葉，匍匐莖 (stolon) 與薯球生長間的分佈，而影響薯球產量與乾物量[2,3]；一般在陽光充足，長日又冷涼的夜溫條件下，植株能營最有效率的光合作用且生育期長，不但產量高，薯球乾物含量亦高，磷肥可促進薯球成熟，增進乾物的含量，而太多氮肥則延遲成熟。

表 4. 產地克雞品種的薯球比重[a]

Table 4. Specific gravity for early planted kenneber

地區與農戶	元月取樣日期	平均產量記錄 T/ha	比重	乾物含量 %
豐原朱氏	2	18	1.081	21.0
潭子黃氏	4	16	1.079	20.4
豐原張氏	7	21	1.080	20.5
神岡劉氏	17	15	1.083	21.2
潭子無名氏	24	—	1.078	20.3

a 克雞種植於九一十月，生育日數自85—97天不等。 田間採收當日逢機取樣薯球測比重

本試驗中，各品種於種植後2—3週即見出土生長，此時地上部的莖葉與地下的根一起生長，約再過2—4週，地下開始長出小薯球，約在種後 1.5—2 個月時，莖葉展幅（Canopy cover）達最大，並維持一段短時間，即開始下降。在2月初連續下雨前，亦即植後80天，不少品種莖葉已呈老化，如 Russet Burbank, Omega, LT-2, Atzimba 等葉片開始轉黃， Red Pontiac 則轉褐紅，而品系 No. 386, 125, 770 等莖葉仍綠，顯示各品種的成熟期不同，但因天雨不能調查各品種的生育日數與成熟期，同時土壤中過多的水分，使薯球達不到成熟（tuber maturity）， 各品種的乾物量都很低（比重低），不能正確指示各品種的正常乾物量（表3與表5相較）。

薯球的生育由最初兩週的滯遲期（lag phase）進入直線生長期（linear phase）、即以一定速率成長，比方在荷蘭馬鈴薯此階段之成長率約爲 800—1,000 kg/ha／天[2]，因此生育期越長，所能獲得的產量當越高，但在本省秋冬短日栽培條件下，馬鈴薯的一般生長型態是地上部莖葉生長有限而薯球早熟[1,2,3,5,6,9,12]。當2月25日採收時，亦即種植後103天，各品種都有 21T/ha 以上的產量，其中 "Hudson" 最高，達 42T/ha ，且薯球大，或者由於其健株率較低，造成株間競爭較小，而使單株產量較高，但1984年的田間觀察也顯示 Hudson 豐產，乾物含量高（表5），唯易罹毒素病，要推廣栽培時，一定需用經由檢疫制度所生產的種薯來種植，才能保證產量。"Russet Burbank" 在美國生長，生育期長達5個月，薯球大而乾物量高，又因其特殊的長形薯球與黃褐色的粗皮，爲消費者認定接受，早在1890年以前即選育推出，迄今仍爲美國第一大品種[4,7,8,10,11,12]，最宜製成薯條，也因此麥當勞要求此品種，但在本省短日栽培條件下，薯球尙不够大 （50—200公克）且未具其特殊的長形，單株產量低，觀察其地上部莖葉之生長有限，而且很快老化，茂綠的地上部只維持到植後60—70天，也使能轉移到地下供球莖生長的養分有限。但較之前季（1984年)之100天 Russet Burbank 的 14T/ha 的產量，今年已提高不少，顯示或可經由單穴選拔，將此品種馴化 ，使在本省栽培能有合乎經濟效益的產量。如果早於九、十月種植，使植株接受充分日照與暖日，莖葉快速生長，並在薯球初生到最大葉面展幅（maximum leaf area）之間，使植株吸收充分氮肥，以維持莖葉茂綠較久，或可提高產量，獲得較大、合乎加工需要的薯球，另於春夏之際，在高冷地種植，給予充分的肥培管理，亦爲一可行途徑，但眞正要了解該品種在本省最適當的栽培條件，還需先探究其營養生理與薯球產量間的關係。

"Atlantic" 由美國農部育成，自 1977年推出後，在美國東部，北自緬因州，南到佛羅里達州，由於它整齊的薯球固形物含量高，適應性廣，成爲甚受歡迎的製薯片品種[4,11]。本所自引進該品種

表 5. 1983—1984調查之薯球比重

Table 5. Specific gravity level for 1983-1984 potato crop at TARI

品　　種	比　　重	乾物含量(%)
LT-2	1.072	19.0
Atlantic	1.084	21.5
Atzimba	1.074	19.4
Hudson	1.082	21.1
Omega	1.080	20.6
Red Pontiac	1.076	19.7
Russet Burbank	1.086	21.9
No. 30	1.065	17.4
No. 125	1.072	19.0
No. 724	1.069	18.0
No. 772	1.076	19.7
720088	1.084	21.5
800301	1.083	21.3
Cardinal	1.081	21.0

經兩季的田間觀察，發現它也能適應本省氣候條件，莖葉生長茂盛，薯大而形美，乾物含量也高達21.5%（1984年測），本試驗中雖產量未達對照品種（26vs29T/ha），但爲能以健康種薯種植，是一個甚有希望的品種，它與『克難』同屬圓白型，但乾物含量却高出『克難』甚多。

品系 No. 386 初期生育較其他品系顯得緩慢，當其他品系已達最大莖葉展幅時，它的莖葉仍繼續生長，植後80天地上部仍茂綠，顯示較晚生，而根據歷年觀察，田間幾不罹病，栽培穩定，薯形略長且整齊，中等大小，將由中興大學植病系利用病毒接種以確定該品系對於本省造成馬鈴薯減產的幾種重要病毒的抵抗性，今年的接種三種病毒，未顯示發病，同時進行接種觀察的尙有品系 No. 770, 455 與 720088 等。東南亞外銷市場喜歡黃皮的小薯品種（歐洲品種則多爲黃皮黃肉），如荷蘭“Bintze”，但在本省尙未種植，“Omega” 也是黃皮小薯，加之薯形整齊，品質亦佳（表5），値得推廣。目前的栽培品種均屬大薯品種，採收後分級，大薯內銷，中小薯外銷，而且對外銷薯的處理較爲粗放，如果種植這種小薯品種，配合適當的栽培距離，專供外銷，將可簡化採收處理。其他品種特性列於表2。

“Kennebec” 於九、十月間種植，當時的充分日照有助於莖葉生長，展幅迅速擴大，而且夜溫自十月下旬即降至 20°C 以下，有助於養分的蓄積，植後70天莖葉仍綠，所取樣的 Kennebec 至少 85 天，其薯球比重 1.078以上合乾物量20.3%以上，而且它的休眠期較其他兩種栽培品種爲長，最易貯藏而不損其乾物含量，只因二月陰雨，中斷此項調查。

結　　論

本省目前只有三個商業品種，而爲因應開拓加工市場的需要，首先想知道 Russet Burbank 在本省是否具經濟價值，同時將其他已經本所多年觀察而選出的一些品種（系）進行比較，結果顯示多

數供試品種均有栽培品種的產量或更高，而且除內銷市場外，也有値得推廣的專供外銷品種。品系 No. 386、770 等不但產量好，田間罹毒素病率低，栽培容易，Russet Burbank 尙有待馴化，配合栽培條件與管理方法的調整，期能儘早在本省適應。Atlantic 爲製薯片品種，也能適應本省風土。但本試驗因氣候因素不能檢定各品種的乾物含量，但 Atlantic、Russet Burbank、No. 386, No. 732 四品種的比重仍較對照品種爲高。本試驗係初步比較，一些有希望推廣的品種（系）必須在產地行較大規模試種比較，才更能確定其適應性與品質。

在沒有新的加工品種能適應推廣之前，Kennebec 與 Cardinal 兩個現有栽培品種均能供應加工市場需要。

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Evaluation of Potato Cultivars for High Yield and Total Solid Content[1]

Shing-jy Tsao[2]

Summary

Potato cultivar evaluation trial with 19 cv. and 2 commercial cv. as check was conducted at TARI, Taichung from November 13, 1984 to February 25 1985. Maximum temperature ranged from 30°C in November to 21°C in February. Minimum temperature ranged from a low of 11°C in January to 14°C in November and early February. The continuous and heavy rainfall in February resulted in low specific gravity (1.039 to 1.060) in tubers with the only exception of No. 732 which had a value of 1,071, corresponding to 18.8% of totalasolids.

Compared to the average yields of check cv. (Cardinal and Kennebec), 14 tested cv yielded same or higher. Hudson led the other 13 cv with a yield of 42 t/ha, however, this variety had a very high susceptibility to viruses. Russet Burbank, thf number one US variety for French fries gave the lowest yield of 21t/ha due to the small tuber size because under short days this variety matures too early and its yield may be improved by appropriate culture management.

The total solids content of Kennebec tubers at farmers' field was assessed after harvest. Specific gravity readings were taken from samples randomly collected at 5 different sites in January. The results showed that when planted in September-October, the crop had good canopy cover and longer haulm growth, all sampled crops had specific gravity of 1.078 or higher which meets the requirement for processing

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Studies on the Production of Seed Tubers from True Potato Seed[1]

Shing-jy Tsao[2]

Abstract : The health standard and yielding ability of first generation TPS tubers were tested. Comparing to commercial cultivars, TPS families had same disease level of 13%. TPS tubers of Atzimba×DTO-28 and PAS 3064 (Hybrids) gave comparable yield (400 g/pl) to cv. Cardinal (380 g/pl). Open pollinated families yielded lower (240 g/pl) and tended to have more haulm growth than tuber bulking. This indicated that selected TPS family could be used to produce seed tubers with good quality which in turn could produce ware potatoes for fresh consumption.

To determin the proper season to produce seed tubers, four plantings representing early and late half of both October and November were compared in terms of total yields, effective tuber (tuber≥8g) percentage and number. For direct seeding in field, late half of October was better because of cooler temperature. The October 29 planting yields the best of 2.6 kg/m^2, of which 92% would be good for seed use in number of 90 per square meter. Again hybrid families yielded higher than the OPs.

Under protection in screenhouse, higher TPS tuber yields were generally obtained. The early October sowing resulted in good seedling emergence and growth when shade was provided. The November 11 planting yielded the best, 3.2kg/m^2 of total tubers and 130 effective tubers/m^2. Evenly distributed transplants (in density of ca. 13×13cm) in screenhouse tended to produce effective seed tubers smaller in size and more in number than directly field sown seedlings.

The first generation TPS tubers whether produced in open field or in screenhouse had disease rate of no significant difference, being 13.3% vs. 20.8% respectively which again was comparable to that of commercial tuber variety. The screenhouse did not guarantee better protection to TPS seedlings from virus infection by contact or insects. The 2 hybrid TPS progenies gave similar yield to Cardinal tuber (34 t/ha) and most tubers were marketable, being of 150g in size in average.

The use of potato true seed(TPS) for production of tubers as planting material has been practiced on farm level in various countries as Sri Lanka[10,13], Rwanda[5], and mainland China[15], while scientists of more than 20 countries have been involved in

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various aspects related to potential adoption of TPS technology, especially the International Potato Center has concentrated much researches in collaboration with other national scientists to develop the most adaptable agronomic technology and improved TPS progenies[4-13,17]. The advantages of using TPS instead using traditional seed tuber propagation include the low cost for producing TPS, elimination of tuber associated diseases and bulky storage and transport.

In Taiwan, although seed certification and a basic-foundation-certified 3 level production system has been established with in vitro tuberlets as basic seed[1,2,3], some farmers still purchase seed tubers produced through non-certification system. The present study conducted during 1983, 1984 and 1985 was a continuation of a series of agronomic experiments aiming to evaluate the technology of using TPS to produce seed tubers and find the most adaptive method to implement here.

Materials and Methods

Comparison between TPS tubers and commercial cultivars

Four commercial cultivars were used in this experiment. They are Atzimba (Mexican variety), Wu-feng, Cardinal, and Kennebec, with the latter three being current commercial varieties. The TPS tubers used were first generation seedling tubers of 10 different families including 3 open-pollinated (OP) and 7 hybrid ones. All tubers were planted whole on November 15, 1984 in a completely randomized design with unequal number of replications for each entry at TARI experimental farm. For the convenience of using a small cultivator, single rows with row spacing of 90cm and 30cm between hills were used. The size of the TPS tubers used were mostly between 10 and 20g while that of commercial cultivars were above 30g. The plants were investigated visually for tuber borne virus symptoms one month after planting and the diseased plants were discarded then to eliminate further infection. The crops were harvested on February 22, 1984 and fresh weight for both haulm and tubers were recorded.

2. Seasonal effect on the production of seed tubers

To study the seasonal effect on TPS germination, plant growth and final tuber yield, 6 tuber families including 3 OPs and 3 F_1s (Table 1) were used in this experiment which was conducted in both open field and screenhouse. Four sowings were taken at 2 week intervals representing early and later half of both October and November (Table 2). The temperature data for these 2 months are shown in Table 3. TPS were directly sown in field at a spacing of 10×10cm on plots of 2.7×1.3m for each family at each of the 2 replications.

For screenhouse planting, TPS were first sown in plastic flats in greenhouse and then transplanted in completely randomized design at spacing of 12×12cm on 85cm wide bed. The close spacing was aimed to produce numerous small tubers for seed. Plants were harvested at the average maturity for each planting, number and weight of tubers were recorded.

3. Comparison between TPS tubers of different sources

TPS produced either in screenhouse or in open field in 1983—1984 season were

compared in terms of their disease rate and yield ability. Tuberlets of 15—20g each were planted on November 16, 1984 in TARI farm in a RCBD with 3 replications. Three tuber families and 2 sources (screenhouse vs, field) formed 6 treatments. Each plot consisted of 2 double row beds of 1.3×6m with 40 hills on each bed. The number of virus symptomed plants were recorded one month after planting and the diseased plants were pulled out. The crops were harvested on March 25, 1985 with 129 days of growth and the tuber yields were recorded.

Results

1. Comparison between TPS tubers and commercial cultivars

The yielding capacity on plant basis of TPS tuber families ranged between 184g and 427g with average yield of 239g for the OPs and 308g for the hybrids. The yields obtained from 4 commercial cultivars ranged from 299g of Kennebec to 567g of Wu-feng with an average of 437g (Table 4). Significant difference existed between cultivars and TPS OP families. Moreover, the OP families produced smaller tubers than either hybrid families or cultivars did, giving only half of the hill being acceptable in terms of tuber size and yield.

Table 1. TPS families used to study seasonal effect.

TPS family	Abbreviation	Genetics
26	26	OP
254	254	OP
475	475	OP
Atzimba × R 128.6	A × R	F_1
DTO-33 × R 128.6	DTO-33 × R	F_1
PAS 3064	3064	F_1

Table 2. Temperature* (C) in October and November of 1983

Date		Max.	Min.	Mean
	1—10	32.9	22.6	27.8
October	11—20	32.0	22.4	27.2
	21—31	29.1	20.2	24.7
	1—10	29.3	15.6	22.5
November	11—20	26.2	14.3	20.4
	21—30	25.3	10.4	17.9

*data taken at TARI, 85m asl.

Table 3. Comparison between TPS tubers and commercial cultivars

Tubers[a]	Hill No.	Disease level %	Tuber yield		avg tuber size (g)
			Per plant (g)	% biological yield	
Cultivar	1960	14.07	437 a[b]	70.5	
Cardinal	1702	9.10	379		68
Kennebec	52	13.52	299		81
F_1 TPS	2445	13.82	308 ab	72.7	
A × DTO-28	1082	12.81	427		64
PAS 3064	334	3.04	382		66
OP TPS	1634	13.10	239 b	64.8	

a. planted on November 15, 1983; harvested on February 22, 1984.

b. Means do not have a letter in common are significantly different at the 5% level according to Ducan's multiple range test.

Selected hybrid TPS families such as A×DTO-28 and PAS 3064 produced tubers comparable to the commercial varieties in size and yield. The morphological uniformity for the above mentioned two TPS families were fairly good in terms of tuber size, skin color (white, except PAS 3064 tubers with red eyes) and shape (mostly oval round). Crops from OP families had vigorous haulm growth but not much of the tuber production in comparison to crops from hybrid families. The average percentage of tuber weight in total biological yield (haulm+tuber) for the OPs, F_1s and commercial cultivars were 64.8, 72.7 and 70.5 respectively (Table 4). Ideal proportion of tuber yield should take at least 70% of the total growth, however, the percentage would be much increased if the haulm was senescent and died down. Tuber weight taking less than 70% of the biological yield probably indicated the unefficient partitioning of photosynthates into tuber bulking which might be of genetic causes or the interaction of genotypes and environment.

2. Seasonal effect on the production of seed tubers

A. Direct seeding in open field

The TPS takes longer time to emerge at earlier sowing date. The percentage of emerged seedlings taken 2 weeks after each planting was shown in Table 5. Sowing on October 12 resulted in the lowest average percentage of emergence, 13%, while later sowing gave more than 40% of emergence. Temperature tended to be major factor for it. The still high temperature in early October slowed and inhibited the seed germination and the gradual decrease in temperature (Table 3) favored the process of germination, resulting faster and more emergence. During growth, natural selection tended to survive the better genotypes by eliminating out weaker seedlings. At young seedling stage, cutworm in soil and damping-off pathogen were main pests. TPS family of PAS 3064 had the earliest maturity since its plants showed first senescence with yellow

leaves at $3\frac{1}{2}$ mo. of planting. However, each planting was harvested according to overall maturity and once for all before all plants turned yellow. The planting of October 29 had the highest tuber yield of 2.61kg/m^2 of which about 92% would be good for seed tubers since they were larger than 8g (Table 6). Ninty seed tubers were produced per square meter. The 2 plantings in November gave lower but not significantly different tuber yield of 2.04 and 2.40kg/m^2, respectively. The November 23 planting gave the highest number of tubers of 8g or more in size, being 108 tubers/m^2. The data indicated the most proper season to direct seed TPS in field for seed tuber production would be from late October on when the temperature was cool enough for germination and still warm enough during the following period for the growth. As for the TPS sources, hybrids generally yield better than the OPs, more than 2.5kg/m^2 vs. about 1.5kg/m^3 (except '254' family) (Table 7).

Table 4. Seasonal effect on TPS emergence % in field[a]

TPS	Oct. 12	Sowing date		Nov. 23
		Oct. 29	Nov. 11	
26	8	43	41	49
254	4	29	47	—
475	11	37	23	47
A × R	23	43	52	53
DTO-33 × R	15	43	38	61
3064	17	54	44	51
average	13	41	41	52

a. Emergenec % was taken 2 weeks of sowing except for Nov. 23 planting which was taken one month of sowing.

Table 5. Seasonal effect on seed tuber production in field

Direct seeding date in 1983	Growing days	Total tuber kg/m^2	≧ 8 g tubers kg/m^2	%	No./m^2
October 12	119	1.96 b[a]	1.76	88.9	70
29	129	2.61 a	2.42	92.0	90
November 11	118	2.04 ab	1.67	78.0	82
23	128	2.48 ab	1.97	77.9	108

Table 6. Seed tuber production of TPS families

TPS family	Total tuber kg/m²	≧ 8 g tubers kg/m²	≧ 8 g tubers %	≧ 8 g tubers No/m²
26	1.57 c[a]	1.29 c	80.9 a	65 b
254	2.41 b	2.04 b	82.5 a	96 a
475	1.39 c	1.16 c	81.1 a	59 b
3064	2.53 b	2.20 b	86.2 a	98 a
DTO-33 × R	2.96 a	2.60 a	87.9 a	108 a
A × R	2.78 ab	2.42 ab	86.7 a	98 a

a. Means do not have a letter in common are significantly different at the 5% level according to Duncan's multiple range test.

B. Transplanting in screenhouse

The November 11 planting yielded the highest of 3.22kg/m² and the highest number of 130 tubers/m² of 8g or more in size. All plantings except the Oct. 29 one in screenhouse had better total tuber yield but same useable tuber yield comparing to the plantings in open field. In terms of the number of effective tubers, all planting gave more than 100 per square meter (Table 8). Unlike those directly sown to field, TPS seedlings under protection in screenhouse had less competition from pests, less attack from adverse weather. The-higher density and evenly distributed plants gave slightly higher total yield but smaller tubers and lesser proportion (about 65% by weight) of effective seed tubers compared to field plantings which gave more than 80% of the total yields as seed tubers. The data indicated that sowing of TPS could be as early as early October if shade provided to lower the temperature.

Table 7. Seasonal effect on seed potato production in screenhouse

Seeding (1983)	Trans planting	Growing days	Total tuber kg/m²	≧ 8 g tubers kg/m²	≧ 8 g tubers %	≧ 8 g tubers No./m²
October 12	November 22	145	2.56 ab[a]	1.66	65.1	105
29	December 2	128	2.27 b	1.53	67.9	103
November 11	December 15	133	3.22 a	2.00	62.1	130
23	January 6, 1984	135	2.60 ab	1.86	71.3	101

a. Means do not have a letter in common are significantly different at the 5% level according to Ducan's multiple range test.

3. Comparison between TPS tubers from different sources

The quality of TPS tubers produced either in screenhouse or in open field was comparable to certified commercial seed tubers of Cardinal in terms of disease rate which was 20.8%, 13.3% and 19.8% for 3 different sources respectively. The tubers of OP family had higher virus infection than those of 2 hybrid families, being 22% vs. 15 % (Table 9). The value was higher than that of previous year. Seasonal effect during seedling growth might be involved. The hybrid families yielded better than OP family with plants being more vigorous along with faster canopy development and probably better partitioning of the assimilates to tuber growth. The tuber yield was 26t/ha for the OPs and 34t/ha for the hybrids, the latter being similar to Cardinal tuber yield. Again, the tuber yields were higher than those obtained in previous year. Both seasonal and soil effects (different field lot) might account for this difference. The tuber uniformity of the hybrid progenies was also acceptable in terms of good tuber size (ca. 150g each), oval round shape and white skin. However, the fairly deep eye in general was inherent defect.

Table 8. Comparison between TPS tubers of different sources[a]

TPS family	Disease rate %			Tuber yield (t/ha)		
	Field	Screenhouse	avg	Field	Screenhouse	avg
A × R	10.0	20.5	15.3	36.1	33.3	34.7
DTO-33 × R	9.2	17.1	13.3	33.6	35.0	34.3
475	20.5	24.6	22.6	26.8	25.5	26.1
avg	13.3	20.8		32.1	31.2	
Cardinal[b]	19.8			33.6		

a. TFS tubers were produced in either screenhouse or open field in 1983—1984 season, they were planted as seed tubers on November 16, 1984.

b. Cardinal tubers were purchased as certified seed and planted in the same field on Nov. 14 with 105 days of growth.

Discussion

Three schemes, proposed for different areas with different situations to use TPS are direct field seeding, transplanting seedlings and producing seedling tubers for proapagtion. Production by seedling tubers and seedling transplants is gegerally better than direct field sowing[5,16,17]. Seedling tubers in turn offer more advantages than transplants by easier to establish, easier management, shorter growing period and large tuders produced with improved homogeneity. It has been successfully used in various countries as a complementary system to national seed program.

Generally TPS tubers are of high health standard, carrying approx. 5% of virus[9]. With optimum environment, they can even be grown for three generations before final

release as seed tubers to large scale farming(7). In present study the virus incidence of the first generation TPS tuber, although being comparable to commercial seed tubers, is much too high, being more than 13%. However, as low as 3% of virus infection was obtained (Table 4). With seasonal effects being considered more intense disease and insect control will be needed to lower the virus incedence. Hybrid TPS progenies in general outyielded OP progenies. Good yield of 34t/ha (Table 9) was obtained by planting first generation F_1 TPS tuberlets. This result is comparable to that of other countries(5,10) and it is expected that by breeding and selection, tuber uniformity and yield will be further improved especially with hybrid progenies. As high as 1.3kg/pl of population mean tuber yield, equivalent to 54t/ha (42,000pl/ha) from TPS family has been reported(12). OP progenies with 40t/ha or more of tuber yield has been obtained (11), OP seeds of an India variety had been widely distributed and tested in India, Bangladesh and Sri Lanka for its high yielding ability. The production of seedling tubers in nursery bed has been reported as high as 10kg/m^2 of total tuber weight and as many as 1,000 or more useable tubers ($\geq$1g)(17). Comparatively, the yield of 3kg/m^2 (Table 8) in weight and a few hundred in number (tubers$\geq$1g counted) from the present study was rather low, giving lower multiplication rate in turn. Various studies (4,11,12,17) have shown that the use of regular field soil as nursery substrates gives poor seedling growth and recommended the use of mixture of sand and compost or subsoil and peatmoss in equal parts with low salt concentration. High phosphorus is essential for good seedling growth. Nitrogen and potassium are applied along with irrigation after seedling emergence. The farm soil used in this study is silt loam in structure with low organic matter in fertility. This along with the low hilling (some tuberlets are found near soil surface) might cause the low yield. The TPS seedlings are usually more sensitive to adverse conditions of soil and temperature than tubers. The optimum temperature for TPS germination is 20°C(6) and the temperature in early October is probably inhibitory to TPS emergence, resulting in slower and lower seedling growth (Table 5), while tubers can be planted in late September in central Taiwan(2). It was therefore recommended to direct seed in late October or earlier seeding should be carri ed out with shade provided to lower the temperature and minimize soil crusting in turn.

The effective tuberlets to be used as seed tuber are 8g or larger in size(1 while tuberlets of 1g are considered useable in other studies(11,17). The smaller tuberlets can be planted but with slower initial growth, if long season provided along with fertile substrates and intense agronomic management, reasonable yield can still be achieved. If the 1g tubers counted, the number of useable tubers will increase in this study.

The seed tubers produced in open field or in screehouse had disease rate of no significant difference, in fact, the value from the screenhouse was higher than that in the open field. This might be caused by much contact from transplanting operation. The screenhouse did not guarantee better protection to TPS seedling from virus infected by contact or insects as long as there is some isolation from other Solanaceae crops in open field.

In concluding the agronomic experiments conducted through years, there may not be possibility of using TPS in commercial production in the near future here in Taiwan where the domestic market favors large size tuber preferably with high dry matter content for processing products and the export market fluctuates. TPS family can hardly take place of commercial varieties for the time being. However, TPS research offers good potential in breeding work especially for disease resistance incorporation. Selection pressure can be applied at the seedling stage to screen out resistant plants to diseases such as late blight and bacterial wilt and the selected tuberlets can be further multiplied and undergone more accurate evaluation. The breeding work for disease resistance is important yet lacking at this stage.

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利用種子生產馬鈴薯之栽培研究[1]

曹 幸 之[2]

摘 要

以馬鈴薯種子來繁殖種薯已在有些國家實行，以彌補健康種薯之不足所造成產量偏低的現象，在本省目前雖由政府支持進行種薯檢疫與生產，但其量仍不足供應每年栽培所需，本所自1980年開始進行由馬鈴薯開花與結種子到各項田間栽培試驗，以探求由種子來生產馬鈴薯在本省的實用性，本研究繼續進行由種子生產小種薯方面的三項栽培試驗，比較栽培品種與實生薯的繁殖程序與產量，比較田間與網室所生產的實生薯，是否在帶病率上有差異，以及最適合生產實生薯的時期。

在不同年度（1983年和1984年）實生薯所帶的病毒率與購自農會的栽培品種採種薯同樣約為13%，一些雜交族羣的實生薯做為種薯時可以得到與栽培品種一樣的產量達 34T/ha，同時株間差異小，薯球大，除了芽眼較深外，外觀上相當一致顯示種植實生薯（每個約在 15—20 g）能够獲得很好的產量，這些實生薯種植容易，不再須經切薯。

種子育苗以十月下旬的溫度較適合播種，在此之前田間溫度仍高，影響種子的發芽，或者苗床必須加以遮蔭以降低土壤溫度，只要避開高溫皆適合播種，幼苗經疏苗或以固定距離移植，在每平方公尺面積上最高可得 3.2kg 的薯球，其中選出達 8 公克以上的薯做為繁殖的薯，可每平方公尺在 100 個以上，而實生薯無論是在田間生產或網室內生產的也都有相同的繁殖率，顯示只要與其他蔬菜作物隔離即可在田間育苗生產實生薯，網室內繁殖實生薯並不一定生產出較不帶病的實生薯。

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轉作田玉米肥料需要量與土壤肥力之關係[1]

連　　深[2]

摘要：本試驗於兩年期間舉辦秋作試驗16處和春作試驗13處，探討臺農351號玉米在轉作田之肥料需要量與土壤肥力之關係，並概定各種要素之需肥診斷基準如下：

（1）各地之玉米施肥效應以氮和磷較高，鉀較低。秋作之氮素需要量平均爲180公斤／公頃左右，其經濟用量平均則約爲165公斤／公頃。氮肥效應之土壤間差異很大，但與有機質含量亦有粗略之負相關；故個別地點之氮需要量可由土壤有機質含量和該地之收量潛力決定。

（2）秋作磷酐的經濟用量平均在100公斤／公頃左右。各地磷肥效應與土壤有效磷測定值有密切關連，其中與 Olsen 氏法之測定值關係較佳。土壤磷之診斷基準與磷肥之推薦量暫定如文中表4。

（3）秋作鉀（K_2O）之經濟用量平均約爲75公斤／公頃。各地之鉀肥效應亦與土壤之置換性鉀或孟立克氏鉀含量有粗略相關。土壤鉀測定值之診斷基準與鉀肥之推薦量暫定如文中表5。

（4）收量6.5噸／公頃之玉米植株三要素吸收量爲 N、P_2O_5、K_2O 各 120、45、100～120公斤／公頃；其中子實之三要素奪取量各爲 85、35、24 公斤／公頃。故 N、P_2O_5 之推薦量各165 和 100公斤／公頃實際上均已超過此等要素之植株全吸收量或子實之奪取量；吸收剩餘之磷肥固可蓄積於土壤中而提高其磷肥力，但剩餘之氮素在土壤中之動向却值得注意。

（5）以上三要素推薦量係以中南部秋作爲主所定。由於北部及東部爲主之春作收量水準顯著低於秋作，其三要素需要量亦較秋作爲低；氮、磷酐、氧化鉀平均需要量各在 100～150、50～100、50 公斤／公頃左右；上述各表中之不同土壤肥力級別磷、鉀推薦量於春作時亦應酌量減少。

又以上各種施肥推薦量係以整地栽培爲主之情形下所定；在不整地情形下因氮肥的揮失、固定等較多而土壤氮的礦化供應却減，其氮推薦量一般應較整地者酌予增高。

（6）玉米葉鎂濃度與土壤中之置換性鎂含量關係不大，却與其置換性鎂／鉀比及葉鉀濃度關係密切，各呈顯著的正、負相關。故土壤中之置換性鎂含量很低固可導致玉米缺鎂，鉀肥施量過多亦會導致缺鎂現象。

在本試驗中雖有少數地點之玉米呈缺鎂徵狀，但施鎂之效果却甚有限，詳細情形尙待進一步試驗。

稻田轉作爲政府既定重要政策，而玉米栽培爲其最重要之一環。行政院核定之「稻米生產及稻田轉作六年計畫，將飼料玉米列爲重點作物，計畫轉作面積至七十八年將累增至八萬五千公頃[(1)]，故玉米栽培面積包括一般旱地，屆時將達十二萬多公頃。

爲配合上項政策之推行，轉作田玉米栽培技術之試驗研究乃爲目前之重要工作，而肥培管理之研究亦爲其重要一環。

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有關玉米之肥培試驗，過去之對象多爲冬季裡作，品種均屬早熟者，而試驗地點則偏於旱作地區。由於新育成之高產品系臺農 351 號係屬中熟、全季型品種，稻田轉作之環境亦與長期旱田之情況迴異，其三素素施肥適量及影響肥料效應之有關營養因素，乃有加以優先探討之必要。

材料與方法

1.試驗地點及土壤理化性質

（1）秋作（九月中、下旬播種，翌年一～二月收穫）：72年在本島中、南部八處，73年在本島中、南部七處及東部一處進行。試驗地點土壤之理化性質如表 1。

表 1. 秋作各試驗地土壤之理化性質

Table 1. Experimental locations and their soil properties (fall crops, 1983 and 1984).

地　點	質　地	pH	有機質（%）	有效性磷（ppm） Bray 1[2]	有效性磷（ppm） Olsen	置換性（ppm） K	置換性（ppm） Mg	非置換性 K(ppm)	母　質	土　系
1893年[1]										
臺中 外埔 表土	L	5.7	1.5	13.8	14.8	41	122	190	砂頁岩冲積紅壤（55公分以下）	臺中本堂村 TPt
臺中 外埔 底土	L	6.4	1.0	3.4	5.7	46	137	170		
臺中 霧峰 表土	SiL	5.0	1.4	3.6	7.9	95	200	255	粘板岩 砂頁岩	臺中七塊厝 TCt
臺中 霧峰 底土	SiL	6.5	1.0	2.5	4.8	62	240	240		
彰化 二林 表土	SiL	7.4	2.0	0	23.7	54	302	210	粘板岩 新冲積	二林 Eh
彰化 二林 底土	SiL	7.8	1.5	0	18.0	56	311	215		
雲林 二崙 表土	S L	7.3	1.6	19.5	15.8	90	178	225	粘板岩 老冲積	二林 Eh
雲林 二崙 底土	SiL	7.5	1.6	27.6	24.8	89	203	243		
嘉義 鹿草 表土	SiCL	6.5	1.9	16.0	16.8	116	509	675	臺灣粘土 老冲積	善化、五甲勢 Sh, Wu
嘉義 鹿草 底土	SiCL	6.4	2.2	16.0	27.2	162	505	725		
臺南 新營 表土	SiL	5.0	1.8	5.2	8.8	104	227	355	同上	五甲勢、後壁 Wu, Hd
臺南 新營 底土	SiCL	5.3	1.3	6.8	12.0	128	276	375		
屏東 新園 表土	SiL	6.0	1.9	21.8	22.7	59	165	215	砂頁岩 老冲積	後壁 Hd
屏東 新園 底土	C L	6.0	1.4	15.4	16.8	53	203	225		
屏東 高樹 表土	SiL	6.1	1.5	50.8	30.5	60	75	115	粘板岩 老冲積	高樹 Ks
屏東 高樹 底土	SiL	5.0	0.9	14.5	11.0	90	95	95		
1984年										
臺中 外埔 表土	L	4.6	2.4	16.1	15.8	56	100	85	砂頁岩紅壤（55公分以下）	臺中本堂村 TPt
臺中 外埔 底土	L	6.0	1.9	5.4	6.1	41	125	105		
臺中 霧峰 表土	SiL	5.3	2.0	14.3	18.3	106	160	153	粘板岩 砂頁岩	臺中七塊厝 TCt
臺中 霧峰 底土	SiL	6.4	1.4	3.5	7.4	45	190	153		
彰化 二林 表土	L	6.7	1.9	12.2	12.9	78	120	191	粘板岩 新冲積	路上厝 Ls
彰化 二林 底土	L	7.2	1.4	4.0	5.5	51	130	182		
嘉義 鹿草 表土	L	7.3	1.9	45.1	45.5	98	195	258	臺灣粘土 老冲積	林鳳營 Lh
臺南 歸仁 表土	SiL	5.9	1.3	39.3	27.8	72	230	258	砂頁岩 新冲積	埤子頭 Pi
屏東 萬丹 表土	SiL	5.9	3.9	23.9	17.9	71	140	147	粘板岩 老冲積	過溪子 Kc
屏東 萬丹 底土	SiCL	7.1	2.4	6.8	9.2	39	150	148		
屏東 萬巒 表土	SiCL	5.1	4.1	28.0	26.1	161	160	113	同上	石光見 Sc
屏東 萬巒 底土	SiCL	6.0	2.5	14.5	16.8	92	180	116		
臺東 關山 表土	SiL	6.5	2.7	5.6	3.4	23	33	82	片岩冲積	瑞穗 Js
臺東 關山 底土	SiL	7.5	2.1	4.6	4.9	16	33	114		

1」表土 0～15cm，底土 15～30cm。　2」抽出液 pH 3.5。

（2）春作（二～三月間播種，六～七月間收穫）：73年在本島東部、北部及中部共八處，74年仍在本島東部及北部共五處進行。試驗地點土壤之理化性質如表2。

表 2. 春作各試驗地土壤之理化性質

Table 2. Experimental locations and their soil properties (spring crops, 1984 and 1985).

地點		質地	pH	有機質 (%)	有效性磷 (ppm) Bray 1[2]	有效性磷 (ppm) Olsen	置換性 (ppm) K	置換性 (ppm) Mg	非置換性 K(ppm)	母質	土系
1984年											
臺東[1] 太麻里	表土	SiL	5.2	2.9	42.9	20.3	43	28		片岩冲積	瑞穗 Js
	底土	SiL	6.1	1.9	9.1	5.8	28	24			
臺東 成功	表土	L	6.3	4.0	25.6	30.2	145	563		黑色土	—
	底土	L	6.9	3.7	20.2	31.3	123	500			
花蓮 玉里	表土	L	5.7	2.6	12.7	7.5	40	39		片岩及粘板岩	瑞穗 Js
花蓮 吉安	表土	SiL	7.3	1.9	0	14.1	38	66		片岩（石灰性）	瑞穗 Js
新竹 竹北	表土	L	4.8	1.9	4.9	6.1	55	213		紅壤母質冲積	南崁溪 Nc
	底土	L	6.3	2.0	3.5	4.1	35	219			
桃園 新屋	表土	SiL	5.0	3.1	34.1	38.0	63	68		紅壤	坡堵 Pu
	底土	SiCL	4.9	1.6	3.4	6.2	34	64			
臺中 霧峰	表土	SiL	5.3		3.9		74		290	粘板岩	—
	底土	SiL	6.5		6.1		56		265	砂頁岩	
雲林 二崙	表土	SiL	6.1							粘板岩	二林、員林 Eh, CYu
	底土	SiL	6.0								
1985年											
臺東 關山	表土	SiCL	6.3	2.3	6.3	9.2	65	130	189	片岩冲積但客有東海岸山脈土	瑞穗 Js
花蓮 光復	表土	L	5.7	3.0	72.5	26.3	35	18	163	片岩冲積	瑞穗 Js
花蓮 鳳林	表土	SiL	5.0	2.5	122.0	55.5	35	15	90	同上	瑞穗 Js
桃園 龍潭	表土	SiC	5.5	1.8	1.5	5.1	51	85	22	紅壤	湖口 Hk
苗栗	表土	L	5.0	2.3	6.9	12.3	116	135	143	砂頁岩	福基 Fc

[1]」，[2]」：同表1.

2.試驗設計及處理

（1）72年秋作及73年春作：除臺中（霧峰）及雲林（二崙）兩地外，各地試驗處理均爲氮3變級，磷3變級，鉀2變級之不完全組合，共六處理，四重複，逢機完全區集。臺中（霧峰）及雲林（二崙）兩地之試驗處理爲氮3變級各二及四重覆，逢機完全區集（但另設無磷區於試驗區外）。栽培方式除了新園一地爲不整地外，餘均爲整地播種。整地栽培者於玉米膝高期培土。肥料施用方法係依照肥料手册(2)所訂標準方法。各地小區面積均爲38.5平方公尺（8～10行區），行株距爲70×25公分。

（2）73年秋作及74年春作：除秋作霧峰一處係磷肥用量試驗外，餘均爲三要素和鎂素之用量試驗；各地試驗處理均爲氮3變級，磷2變級，鉀3變級，鎂2變級之不完全組合，共八處理五重覆，逢機完全區集。霧峰一地之試驗處理爲磷3變級，四重覆，逢機完全區集。各試驗地之栽培方式均爲

整地播種。肥料施用方法，試驗小區面積及行株距均與72年秋作、73年春作相同。

3.調査分析項目

（1）試驗地土壤之理化性質：於試驗開始前自各試驗地採取表土（0～15公分）和底土（15～30公分）測定質地、pH 和有機質、有效性磷鉀、置換性鉀鎂、非置換性鉀等含量。其中 Bray 氏第一法磷係以 pH3.5 0.025N HCl-0.03N NH_4F 抽出；磷鉬酸銨之還元則使用 L-Ascorbic acid。另採土壤剖面標本以瞭解所屬土系。

（2）雌穗吐絲期穗葉 N P K Ca Mg 等各種要素含量。

（3）穀收量。

結果與討論

1.秋作三要素施肥效應與土壤肥力之關係

秋作各試驗地氮、磷、鉀及鎂不同平準之玉米收量如表3。

表 3. 秋作各試驗玉米收量（臺農351號，t/ha）

Table 3. Grain yield (t/ha) of Tainung 351 at various locations and with different rates of fertilizers (fall crops, 1983 and 1984).

1983年

要素用量（kg／ha）			外埔	二林	鹿草	新營	新園	高樹	霧峰	二崙	全試驗地平均
N	P_2O_5	K_2O									
100	100	50	6.18	8.00	6.57	5.23	6.18	6.92	5.21	8.23	6.57
150	100	50	7.18	8.21	7.07	6.57	6.36	7.61	—	—	7.14
200	100	50	7.29	8.70	7.21	5.69	6.28	7.33	6.36	8.40	7.16
300	100	50	—	—	—	—	—	—	6.50	8.01	—
150	0	50	5.95	8.08	6.69	6.27	6.34	7.31	—	—	6.77
150	50	50	6.78	8.15	6.94	6.49	6.15	7.13	—	—	6.94
150	100	100	7.39	8.88	6.71	6.40	6.16	7.24	—	—	7.13

1984年

要素用量（kg/ha）				外埔	二林	歸仁	鹿草	萬丹	萬巒	關山	霧峰	全試驗地平均
N	P_2O_5	K_2O	MgO[1]									
100	150	50	—	4.30	5.62	6.29	5.71	6.76	5.04	5.37	—	5.58
150	150	50	—	4.77	6.40	6.35	5.89	6.86	5.14	5.80	5.37	5.89 5.82[2]
200	150	50	—	5.03	6.89	6.86	6.26	6.54	4.79	5.21	—	5.94
150	0	50	—	4.34	5.83	6.17	5.57	6.69	5.08	3.45	4.90	5.25[2]
150	75	50	—	4.70	6.64	6.30	5.79	6.88	5.23	5.39	5.13	5.76[2]
150	150	0	—	4.21	5.34	6.28	5.69	6.65	4.98	5.15	—	5.47
150	150	100	—	4.78	7.14	6.52	6.03	6.86	5.15	5.88	—	6.05
150	150	50	145	4.81	6.44	6.55	5.91	6.86	5.45	5.63	—	5.95

[1]」使用硫酸鎂 500kg/ha（以含有 MgO 29%計算）。

[2]」8處試驗地平均，餘均爲7處試驗地平均。

各試驗地氮、磷、鉀不同平準之玉米收量（包括各區集），經變方分析結果獲悉地點間差異非常顯著。收量對氮、磷、鉀不同平準之效應除72年秋作鉀肥（僅設二變級）外，亦均甚顯著；其中直線效應均較曲線效應顯著。氮、磷、鉀各種要素之效應與地點之間均有顯著的交感，顯示各種要素之效應因地而異。

由表 3 各試驗地氮、磷、鉀不同平準之玉米平均收量可以描繪玉米收量之各種要素平均效應曲線，如圖 2 、圖 3 （上及下左）及圖 6 （上及下左）。此等圖顯示玉米收量對氮和磷之效應較高，鉀之效應較低。由此等圖亦可以推測最高收量之氮、磷、鉀肥需要量及其經濟用量。爰依各要素別檢討肥料需要量，並探討其與土壤肥力之相關。

（1）氮 肥

由圖 1 可見72年各試地收量水準顯著高於73年，但兩年之氮肥效應趨向相同；由各氮肥效應曲線可求得最高產量之氮需要量，兩年均爲 180公斤／公頃左右， 再以硫酸錏氮素價格每公斤30元，另加施肥費用 1 成計（33元，合玉米2.2公斤），可求得其經濟用量兩年均爲165公斤／公頃。

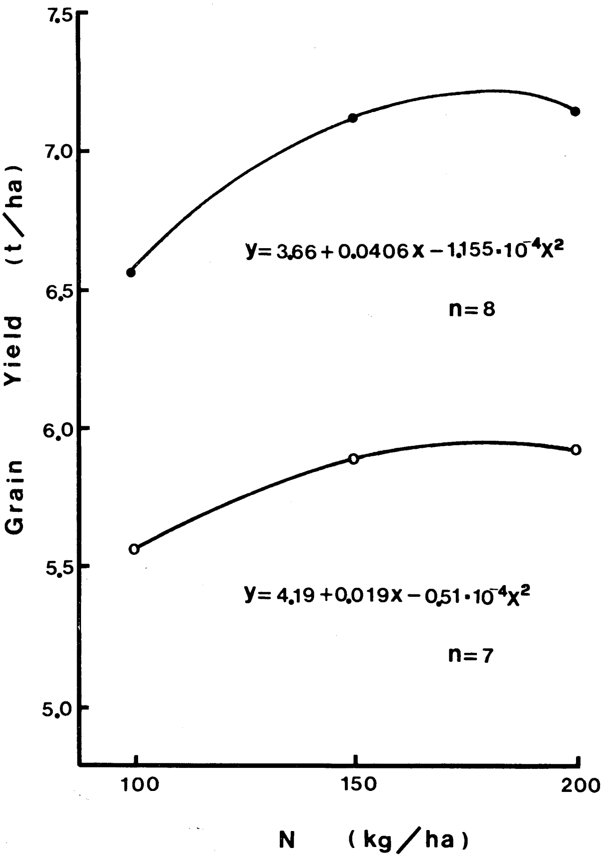


圖 1. 秋作各試地玉米產量之平均氮肥效應（ • 1983 ○ 1984）

Fig 1. Response of Tainung 351 to different levels of nitrogen (fall crops, 1983 and 1984).

氮肥效應之土壤間差異很大，但尙可求得其與土壤有機質含量之關係如圖 2 。由該圖可見有機質含量低的土壤氮肥效應之機會顯然較多，但由於此種土壤之其他生長限制因子亦是較多，氮肥效應未能如期顯現的亦是較多，故氮肥需要量，除了土壤有機物含量外，尙需考慮該地之收量潛力因素。

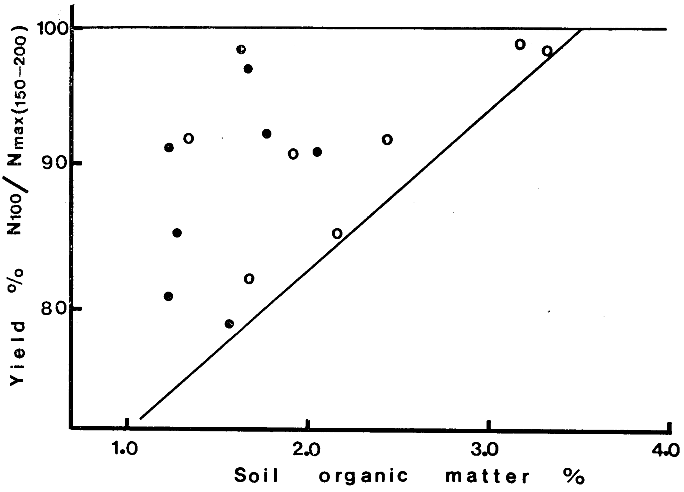


圖 2. 各試驗地玉米產量之氮肥效應（N100區收量除以N150-200最高產量區收量，乘以 100）與土壤有機質含量之關係（• 1983秋作，o 1984秋作）

Fig2. Relationship between soil organic matter content and percent yield responses of corn to nitrogen (fall crops, 1983 and 1984).

（2）磷 肥

各試驗地之平均及不同肥力別磷肥效應如圖 3 。1983 年因所設磷酐平準最高僅 100公斤／公頃，收量之效應未見極限（圖 3 上）。1984 年磷酐施用平準提高至 150 公斤／公頃後，此缺點已獲改善（圖 3 下左）。

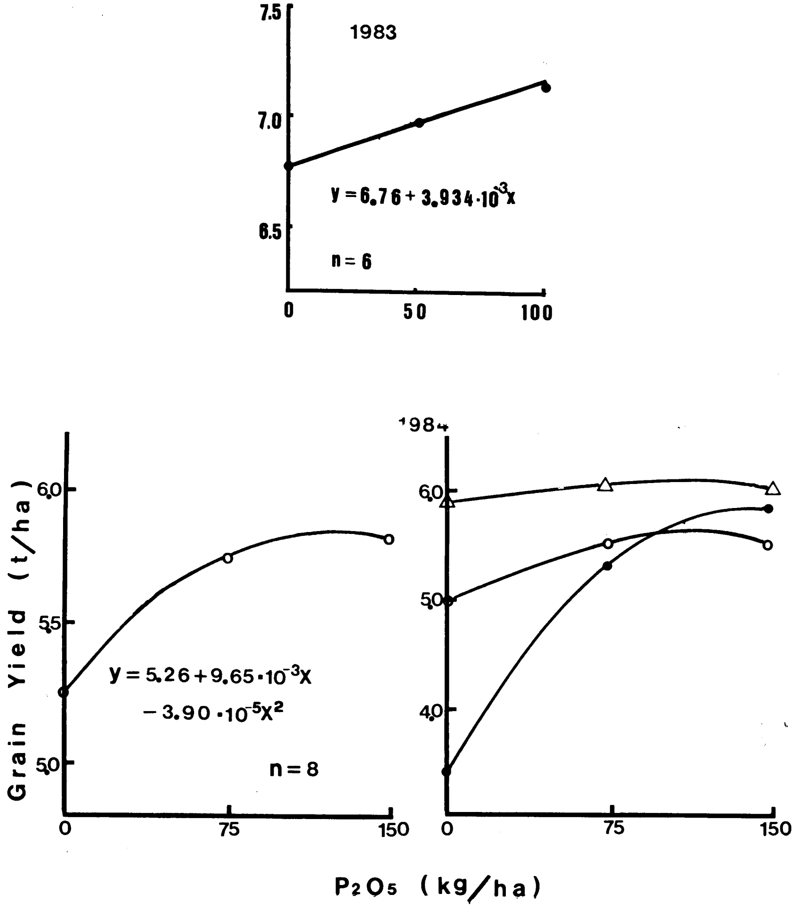
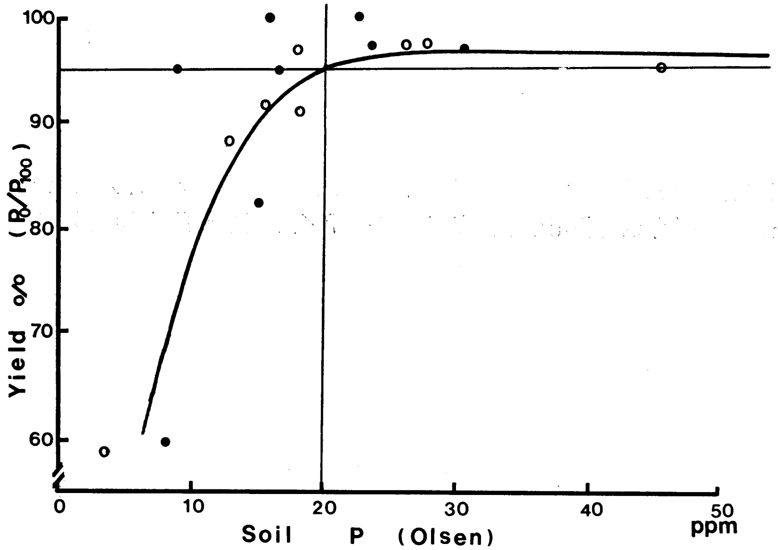


圖 3. 各試地玉米產量之平均和不同肥力別磷肥效應（臺農 351 號，1984秋作）左：8 個地點平均，右：△-△歸仁、鹿草、萬丹、萬巒平均，o—o霧峰、外埔、二林平均，•—•關山。

Fig 3. Response of Tainung 351 to different levels of phosphate(Left: mean of 8 locations. Right: △-△, o-o, •-•; locations with high, medium and low phosphate fertility, respectively,fall crop,1984),

由該圖可求得最高產量之全試驗地平均磷酐需要量爲 124公斤／公頃，再以過磷酸鈣磷酐價格每公斤24元，另加施肥費用一成計(26.4元，含玉米 1.76公斤)，可求得其平均經濟用量爲100公斤／公頃。另由圖 3（下右）可見不同肥力別土壤間之磷肥效應有很大差異；歸仁、鹿草、萬丹、萬巒等地之磷肥力屬中高（表土 Olsen P 18～46ppm, Bray P 24-45ppm)，磷酐需要量低，在 50公斤／公頃以下；霧峰、外埔、二林等地之磷肥力屬低（表土 Olsen P 13～18ppm, Bray P 12-16ppm)，其磷酐需要量在 75公斤／公頃左右；關山一地之磷肥力屬極低（表土 Olsen P 及 Bray P 各 3.4 及 5.6ppm）其磷酐需要量高達150公斤／公頃。

圖4.係依據 Cate and Nelson [3] 不連續模型的原則所畫玉米產量反應百分率（P_0/P_{100}）與土壤有效性磷測定值之關係。由此圖可見95%磷效應之表土有效性磷臨界值 Olsen P 及 Bray P 各爲20及 19ppm 。圖 5 係同圖 4 資料依據 Mitscherlich 氏模式所畫；可見兩種土壤有效磷測定值與磷



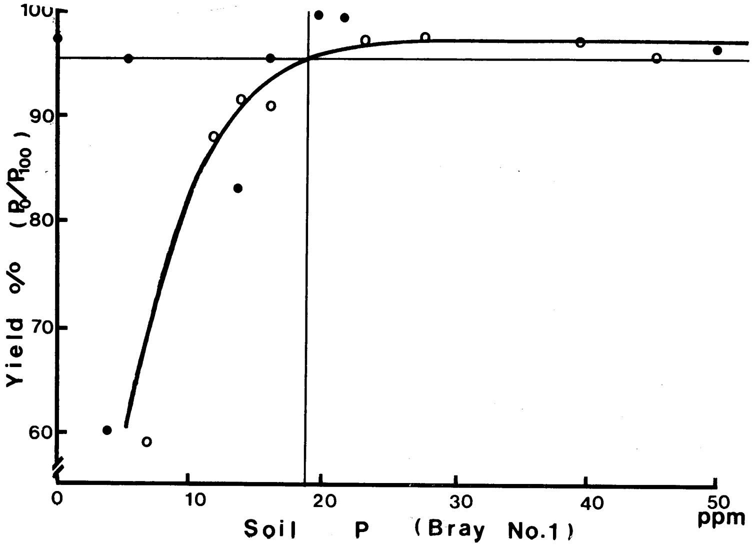
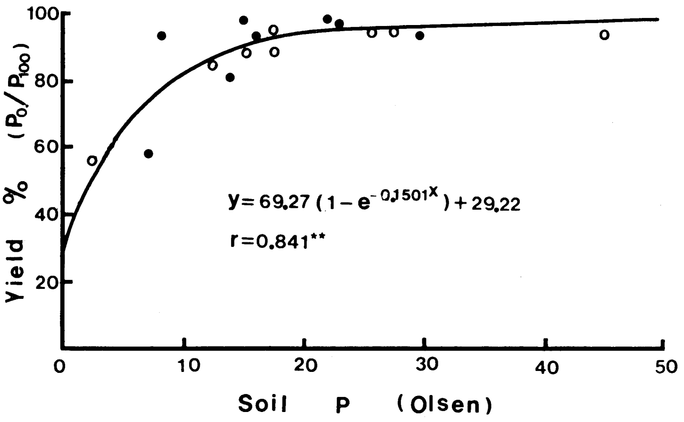


圖 4. 依 Cate and Nelson 原則所畫各試地玉米產量之磷肥效應（P_0/P_{100}）與表土有效性磷值之關係（• 1983秋作，○ 1984秋作）

Fig 4. Relationship between soil test values for P by Olsen's and Bray No. 1 methods and percent yield responses of corn as plotted according to Cate and Nelson's model(fall crops, 1983 and 1984).

肥效應之相關以 Olsen 氏法較 Bray 氏第一法爲佳 ($r=0.84$) 。其有效性磷之臨界值亦各在 20ppm 左右，與圖 4 結果相似，而土壤有效磷值如測表土與底土之平均則與磷肥效應之相關更佳 ($r=0.94^{**}$) 。



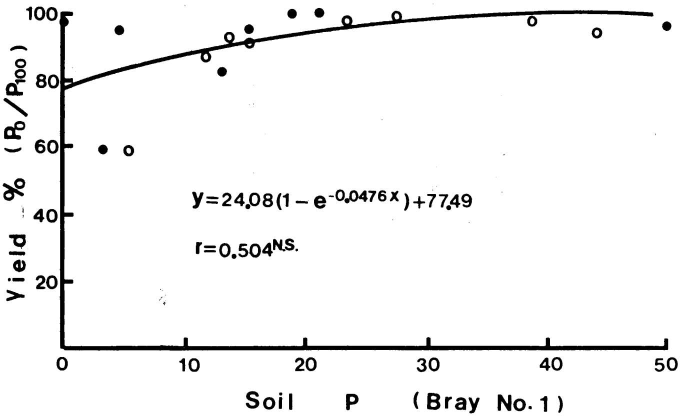


圖 5. 依 Mitscherlich 模式所畫各試地玉米產量之磷肥效應 (P_0/P_{100}) 與表土有效性磷值之關係 (• 1983秋作，o 1984秋作)

Fig 5. The same as in Fig 4 plotted according to Mitscherlich's model.

以上試驗結果所示磷肥效應之土壤有效性磷臨界值較 Hanway 氏[4] 所示磷肥效應之土壤基準值 (10ppm) 爲高，但與過去林家棻氏[5] [6] 以秋裡作臺南 5 號玉米試驗所測 (Bray P, 20–50ppm) 比較却低。經研究結果獲悉同爲 Bray 氏第一法，過去所用之抽出液 pH 值與現行者不同；過去所用者係將 1 規定氟化銨 15ml 與約0.5規定之鹽酸 (以 SP. G. 1.19 鹽酸 20.2ml 稀釋成 500ml 配製) 25ml 配成 500ml 後不另標定；其 pH 值常在 2.5上下變動，因此測定值之變動較大。新法則將二者配成後將 pH 值調至 3.5，因此測定值變動較小，同時由於 pH 值顯著高於舊法，所測磷值亦較舊法所測得者低落甚多。據報告[7] 二者之關係式爲：$P_{3.5}=-1.893+0.629\ P_{2.6}$；故 pH 3.5 抽出液之測值 20 ppm 相當於 pH2.6 抽出液之測定值 35 ppm。故本試驗所示磷肥效應之臨界值 20 ppm，實質上並不低於林氏所報告者[5] 。

玉米吐絲期葉磷的磷肥效應臨界濃度，據 Tyner (1946) 及 Dumenil (1961) 各爲0.29及0.28～0.32 %[8] 。Voss 等 (1970) [8] 則指出期望最高收量的葉片養分濃度係隨着各種環境因子，諸如：玉米連作年數 (牧草後) ，植株密度，土壤生產潛力等而變，强調葉片養分濃度準基值之可變性。渠等示在 Iowa 的 marshall 和 monona 一般情形下，可望95%最高收量的葉片濃度爲0.28%。本

試驗亦示磷肥效應與葉磷濃度略有相關，但變異相當大：在極低（<0.25%）的情形下才可確定缺磷（圖略）。

由以上磷肥效應與土壤有效性磷值之關係以及不同磷肥力地點之磷肥效應曲線可以歸納土壤之磷肥效應診斷基準及磷酐之推荐量如下：

表 4. 表土有效磷測定值與磷肥推荐量

Table 4. Soil testing values for P and the suggested P fertilization.

土壤有效磷含量 (ppm)		P_2O_5 (kg/ha)
Olsen	Bray No. 1	
< 10	< 9	100 ~ 150
10 ~ 20	9 ~ 19	50 ~ 100
20 ~ 30	19 ~ 29	50
> 30	> 29	0 ~ 50

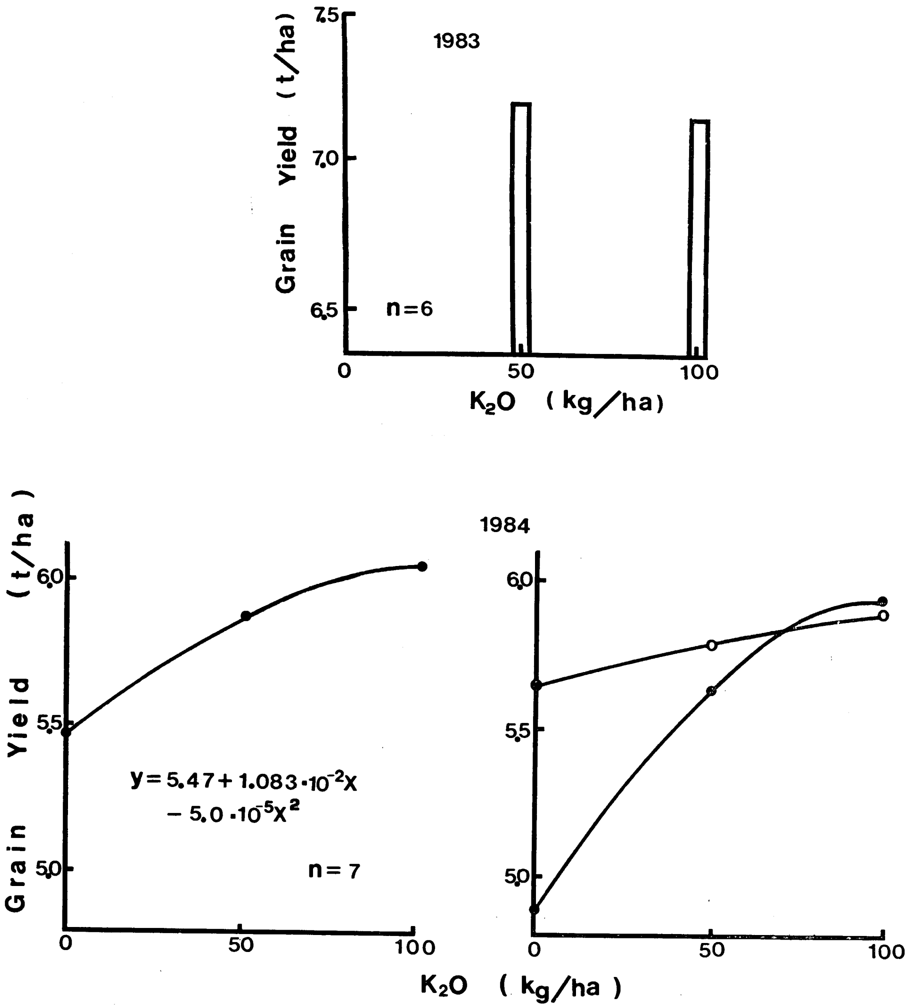


圖 6 各試地玉米產量之平均和不同肥力別鉀肥效應（臺農351號，秋作）上：1983年6個地點平均。下左：1984年7個地點平均，下右：o—o1984年萬巒、歸仁、鹿草平均，●—●1984年二林、外埔、關山平均

Fig 6. Response of Tainung 351 to different levels of potash(Above and left: mean of 6 and 7 locations respectively in 1984 and 1985. Right: o-o, ●-●; locations with high and low potash fertility).

（3）鉀　肥

各試驗地之平均及不同肥力別鉀肥效應如圖6。由圖6（上及下左）可求得最高產量之全試驗地平均氧化鉀需要量爲 50～108公斤／公頃，再以氯化鉀中氧化鉀價格每公斤 13元，另加施肥費用 1 成計（14.3元 合玉米0.95公斤），可求得其經濟用量爲50～99公斤／公頃，平均則約爲75公斤／公頃。另由圖6（下右）可見萬巒、歸仁、鹿草之表土置換性鉀含量高(72-161 ppm）鉀肥效應較低（50公斤／公頃左右），而二林、外埔、關山等之表土置換性鉀含量低（23-78 ppm），鉀肥效應則高（100公斤／公頃）

以玉米產量百分率（K_0/K_{100}）所示鉀肥效應與表土的置換性鉀含量有粗略的相關關係（圖6）（與表土和底土測定値平均之關係則更佳），與吐絲期葉片之鉀素濃度亦略有相關（圖略）；置換性鉀吵量 80ppm 可爲95%效應之臨界値。置換性鉀含量與孟立克氏鉀含量有顯著的相關，但與非置換性鉀含量則否（圖8）。

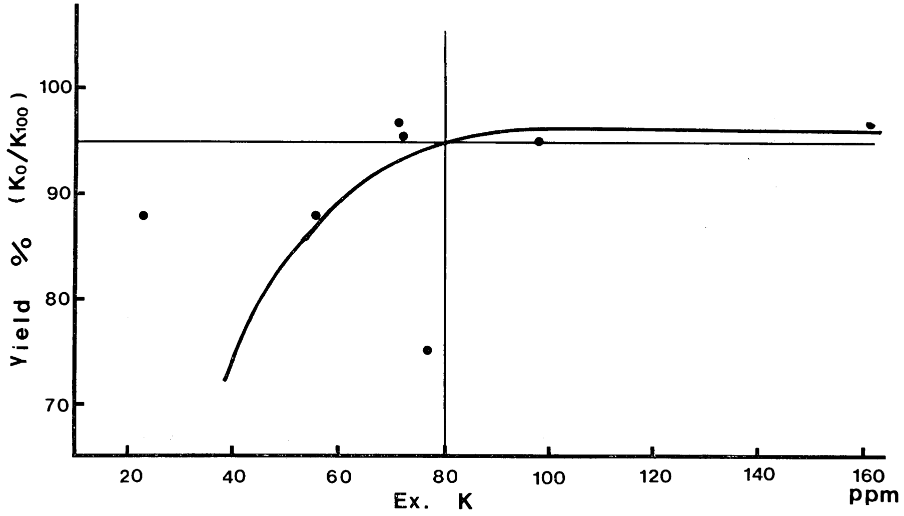


圖 7　玉米產量反應百分率（K_0/K_{100}）與表土交換性鉀含量之關係（1984秋作）

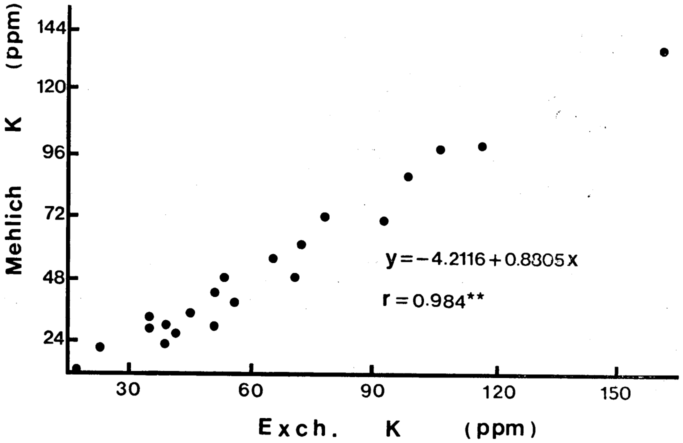
Fig 7. Relationship between exchangeable potassium content of soil and percent yield responses of corn to K (fall crop, 1985).

由鉀肥效應與表土交換性鉀含量之關係以及不同鉀肥力地點之鉀肥效應曲線可以暫定土壤之鉀肥效應診斷基準及氧化鉀推荐量如下：

表 5.　表土有效鉀測定値與鉀肥推荐量

Table 5. Soil testing values for K and the suggested K fertilization.

有效性鉀含量 ppm		K_2O
置換性鉀	孟立克氏法	(kg/ha)
＜ 60	＜ 50	100
60 ～ 80	50 ～ 66	50
＞ 80	＞ 66	0 ～ 50



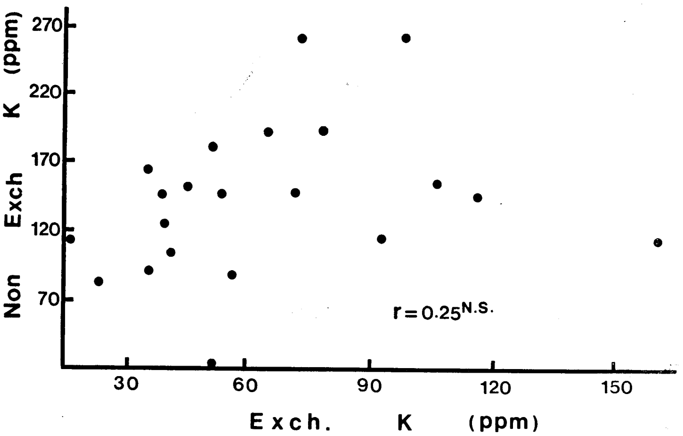


圖 8 置換性鉀含量與孟立克氏法有效鉀和非置換性鉀含量之相關（1984秋作和1985春作 表底土樣本共21個）

Fig 8. Relationship of the content of exchangeable K with those of Mehlich's K and non-exchangeable K (Total of 21 soils including surface and subsurface soils from the locations in 1984 fall and 1985 spring crop experiments).

以上轉作田臺農351號秋作玉米之三要素推荐量（N、P_2O_5、K_2O 各165、100、75 公斤／公頃）高出水稻[(2)]甚多，較過去以臺南 5 號爲主之玉米施肥推荐量[(2)]亦高；可見稻田轉作由於土壤條件特殊及由於所栽培玉米品種之收量潛力高，其肥料需要量亦是較高。

（4）肥料推荐量與作物吸收量

據本試驗分析結果收量 6.5噸／公頃之玉米植株三要素吸收量爲 N、P_2O_6、K_2O各120、45、100～120 kg/ha；其中子實之三要素奪取量各爲 85、35、24 kg/ha。故 N、P_2O_5 之推荐量各165和100 kg/ha 實際上均已超過由此等要素之植株全吸收量或子實之奪取量；吸收剩餘之磷肥固可蓄積於土壤中而提高其磷肥力，但剩餘氮素在土壤中之動向却值得注意。玉米植株的鉀素吸收量雖然很高（100～120 kg/ha），但由於土壤中的鉀素供應豐富，本試驗所示鉀肥效應並不高。由於玉米收獲後之殘渣即使在田間燒却，所含鉀素亦將殘留於土壤，故 K_2O 50～75 kg/ha 之鉀肥推荐量已足可支付玉米子實自土壤的奪取量。

2.春作之三要素施肥效應

春作各試驗地玉米收量如表 6。其中73年太麻里、成功、玉里和二崙之氮、磷、鉀效應如圖 9（

新屋、竹北、吉安及霧峰四地因收量太低，不正常不予檢討）。由圖9可見以北部和東部地區爲主之春作玉米收量水準顯然低於以中南部地區爲主之秋作，其三要素需要量亦較秋作低；氮、磷酐、氧化鉀各在100～150，50～100，50公斤／公頃左右。

74年之試驗結果亦與73年大致相同。

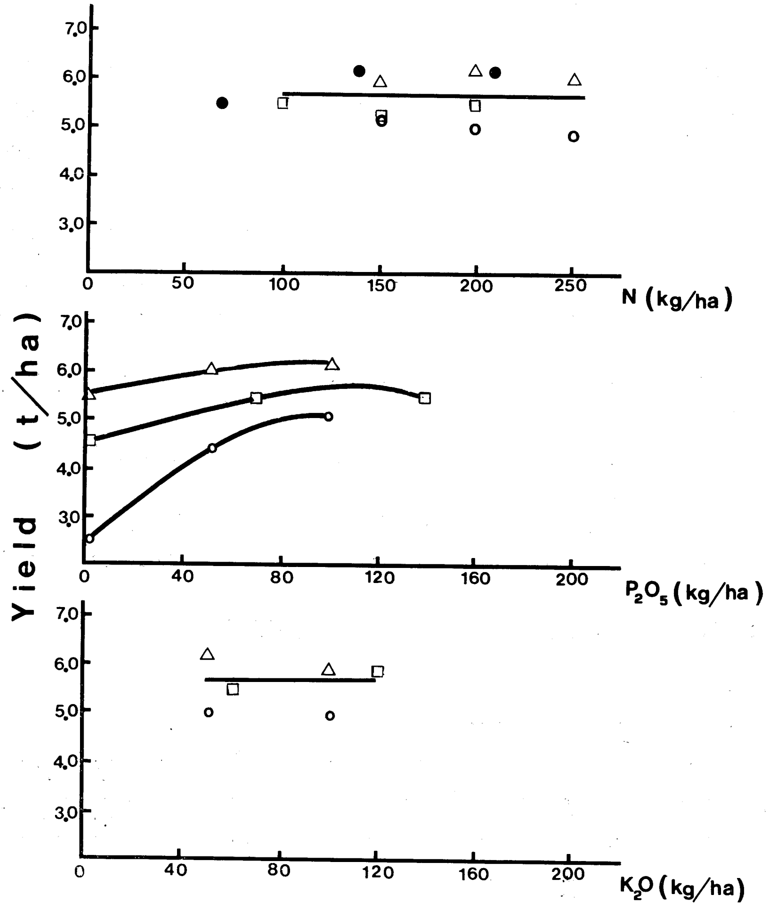


圖 9　各試驗地玉米收量之三要素平均施肥效應（臺農351號，1984春作，○大麻里，△成功，□玉里，● 二崙）

Fig 9. Response of Tainung 351 to different levels of fertilizer elements (Spring crop, 1984).

以上各種要素之施肥推荐量係以整地栽培爲主之情形下所定。在不整地情形下因氮肥的損失、固定較多，而土壤氮的礦化供應却減，故氮肥的需求量增多。本試驗雖無針對此問題加以探討，但據 Well 氏[9]報告，不整地栽培下之氮素推荐量一般都較整地者多30公斤／公頃左右。

表 6.　春作各試驗玉米收量（臺農351號，t/ha）

Table 6. Grain yield (t/ha) of Tainung 351 at various locations with different rates of fertilizer elements (spring crops, 1984 and 1985).

1984

要素平準[1]			太麻里	成功	玉里	吉安	新屋	竹北	霧峰	二崙
N	P_2O_5	K_2O								
1.0	2.0	1.0	5.22	5.95	5.53	3.21	0.98	2.20	3.69	5.54
1.5	2.0	1.0	5.01	6.12	5.28	3.34	1.19	2.15	4.65	6.11
2.0	2.0	1.0	4.84	5.98	5.48	3.45	1.01	2.07	4.84	6.15
1.5	0	1.0	2.52	5.59	4.72	3.37	0.96	0.79	—	—
1.5	1.0	1.0	4.45	6.04	5.42	3.32	0.91	1.91	—	—
1.5	2.0	2.0	4.98	5.88	5.87	3.93	1.19	1.67	—	—

1985

要素用量(kg/ha) N	P_2O_5	K_2O	Mgo	苗栗	龍潭	鳳林	光復	關山	平均
100	100	50	—	6.19	5.40	2.41	2.99	4.26	4.25
150	100	50	—	6.86	5.94	2.70	3.74	4.66	4.78
200	100	50	—	6.78	5.55	2.80	3.46	4.68	4.65
150	0	50	—	5.47	3.59	2.75	2.99	3.09	3.58
150	50	50	—	6.62	5.86	2.82	3.59	4.07	4.59
150	100	0	—	6.37	5.94	2.63	3.75	4.67	4.67
150	100	100	—	6.52	5.77	2.80	3.71	4.96	4.75
150	100	50	145	6.14	5.99	2.72	3.98	4.68	4.70

1)：太麻里和成功：氮1.0，1.5，2.0平準各代表氮150，200，250公斤／公頃。磷和鉀1.0平準各代表 P_2O_5 和 K_2O 各50公斤／公頃，其他類推。

玉里：氮1.0，1.5，2.0各平準代表氮素100，150，200公斤／公頃。磷和鉀1.0平準各代表 P_2O_5 70公斤／公頃及 K_2O 60公斤／公頃，餘類推。

吉安：氮同玉里。磷和鉀1.0平準各代表 P_2O_5、K_2O 各95及80公斤／公頃，餘類推。

竹北：氮同玉里、吉安。磷及鉀1.0平準各代表 P_2O_5、K_2O 各75及50公斤／公頃，新屋，三要素各平準同太麻里、成功。

霧峰、二崙：氮1.0，1.5，2.0平準各代表氮70，140，210公斤／公頃。

3.鎂肥之效應

(1) 葉片鎂、鉀濃度之關係及鎂之缺乏

葉片之鎂濃度與土壤置換性鎂含量相關甚微（圖10上），但與土壤之置換性鎂／鉀比關係却甚顯著（圖10下）。葉鎂濃度與葉鉀濃度有顯著的負相關，而其他要素之間則無任何顯著的相關（表7）。可見玉米植體之鎂吸收受土壤中鉀素濃度或鉀肥用量影響甚大；土壤中置換性鎂含量低固可導致玉米缺鎂，鉀肥用量過多亦會導致缺鎂現象。

表 7 玉米葉片各種要素濃度之相關係數（關山，1984秋作）

Table 7. Correlation coefficients between contents of various elements in the leaves of plant at knee high and silk stages (Kuan-shan, fall crop, 1984)

	膝高期 (knee high stage)				吐絲期 (silk stage)		
	P	K	Ca	Mg	P	K	Mg
N	− 0.09	0.43	0.42	− 0.24	− 0.47	0.19	− 0.19
P		− 0.24	− 0.55	0.19		− 0.26	0.21
K			− 0.25	− 0.86**			− 0.97**
Ca				0.40			

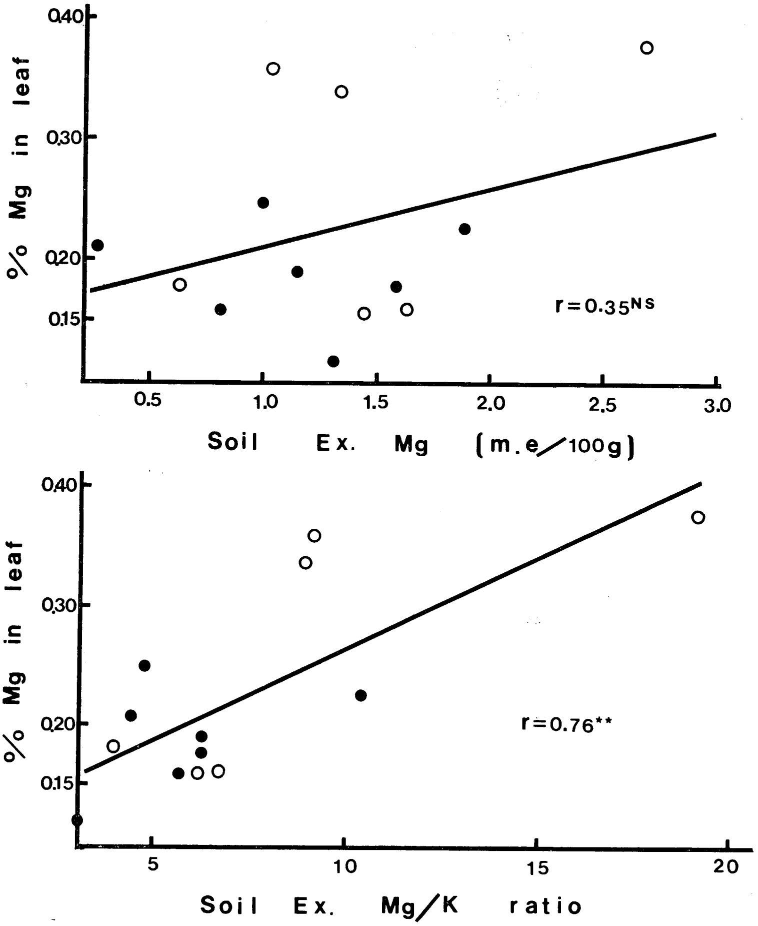


圖 10　吐絲期葉片鎂濃度與土壤置換性鎂含量及鎂／鉀比之關係（○ 1983秋作，● 1984秋作）

Fig 10. Relationship of the content of Mg in leaf with that of exchangeable Mg (above) and the ratio of exchangeable Mg/K content (bottom) in the soils (fall crops, 1983 and 1984).

（2）施用硫酸鎂之效果

由田間觀察，吐絲期葉片之鎂素濃度在0.16%以下者常有缺鎂症狀出現。據報告[10]缺鎂之葉鎂臨界濃度因作物種類和時期而略異；玉米抽穗期雌穗位葉為0.25%（標準機差0.08%），大豆幼莢形成期剛成熟葉（含葉柄）則為0.30%（標準機差0.15%）。

本試驗中葉鎂濃度特低之地點為萬巒、光復和龍潭（表8）。其中萬巒和光復二地固然表現施鎂效果，惟究竟不高（僅增產6%左右，未達顯著標準），而龍潭則全無施鎂效果表現。

光復於施用硫酸鎂後葉鎂濃度有顯著的增高，但萬巒和龍潭之葉鉀濃度很高；其施鎂後葉鎂濃度之未能增高或與此有關。

總之，本試驗中雖有少數地點呈缺鎂徵狀，但施鎂效果却甚有限；詳細情形尚待檢討。

表 8. 各試驗地土壤置換性鎂、鉀含量，植物體鎂、鉀含量及施硫酸鎂效果

Table 8. Contents of exchangeable Mg and K in soil, that of Mg in plant and the effect of magnesium sulfate application at various locations (fall crop 1983 and 1984, and spring crop 1985).

試驗地點	置換性 (me/100g)			膝高期葉片 (%)			吐絲期葉片 (%)			穀收量 (t/ha)	
及期作	Mg	K	Mg/K	Mg	K	Mg*	Mg	K	Mg*	對照區	硫酸鎂區
1983秋作											
外埔	1.03	0.11	9.4	—	—	—	0.36	1.56	—	—	—
二林	2.69	0.14	19.2	—	—	—	0.38	1.85	—	—	—
高樹	0.62	0.15	4.1	—	—	—	0.18	2.28	—	—	—
新園	1.36	0.15	9.1	—	—	—	0.34	1.64	—	—	—
霧峰	1.64	0.24	6.8	—	—	—	0.16	2.50	—	—	—
二崙	1.46	0.23	6.3	—	—	—	0.16	2.86	—	—	—
1984秋作											
外埔	0.82	0.14	5.9	0.25	4.03	0.28	0.16	1.78	0.18	4.77	4.81
二林	0.99	0.20	5.0	0.46	3.94	0.33	0.25	1.89	0.23	6.40	6.44
歸仁	1.89	0.18	10.5	—	—	—	0.23	2.09	0.24	6.35	6.55
鹿草	1.60	0.25	6.4	—	—	—	0.18	2.09	0.16	5.89	5.91
萬巒	1.32	0.41	3.2	0.16	2.16	0.18	0.12	2.35	0.13	5.14	5.45
萬丹	1.15	0.18	6.4	0.23	2.19	0.22	0.19	2.16	0.21	6.86	6.86
關山	0.27	0.06	4.6	0.15	3.01	0.17	0.21	1.78	0.21	5.81	5.63
1985春作											
關山	1.07	0.17	6.3	0.41	4.04	0.43	0.17	2.17	0.20	4.66	4.68
光復	0.12	0.09	1.3	—	—	—	0.12	1.30	0.21	3.74	3.98
鳳林	0.15	0.09	1.7	—	—	—	0.18	0.84	0.25	2.70	2.72
龍潭	0.70	0.13	5.4	—	—	—	0.091	2.76	0.11	5.94	5.99
苗栗	1.11	0.30	3.7	—	—	—	0.17	1.85	0.19	6.86	6.14

*硫酸鎂區

4.玉米收量之土壤間和期作間差異

玉米收量之土壤間差異甚大；以秋作而言，各試地玉米收量在5.0~8.4噸／公頃之間(表 3)。據田間觀察，土壤之物理性及磷的肥力似爲影響玉米收量之最主要因素；質地較粘，構造緻密，水滲透性不良者產量較低。此種土壤如於播種時遇雨則影響種子之發芽，並由於土壤構造緻密及磷肥力不高，影響玉米對磷素的吸收，致使其初期生育較差，如新營、霧峰等地是。反之，質地屬砂質壤土而土壤 pH 值又都在中性以上者，非但耕作容易，玉米生育亦較良好，收量較高，如二林、二崙，高樹等地是。

春作之收量水準顯著低於秋作；以二崙一地爲例其秋作收量高達8.4噸／公頃，春作却僅及6.2噸／公頃，其生育上之差異將於另報討論。新屋和竹北之收量只及 1 ~ 2 噸／公頃，係因玉米播種後春雨連綿，生育不良所致。可見北部地區並不適合於玉米之春作栽培，但其秋作由於玉米成熟期間季節風大，亦不見得適合於玉米之栽培。

誌謝：本試驗經費承農委會73農建—2.1—產—125（丙）號及74農建—2.2—糧—27（13）號計畫補助，田間試驗承桃園區農業改良場曾潤錦先生，臺中區農業改良場徐國男先生、臺南區農業改良場謝元德先生、高雄區農業改良場羅瑞生先生、臺東區農業改良場張茂盛先生、花蓮區農業改良場陳忠明先生及本所王鑪和先生分別擔任，並蒙陳春泉先生鑑定試驗地土壤母質及土系，一併誌謝。

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Fertilizer Requirements of Corn in the Drained[1] Paddies Related to Soil Fertility[1]

S. Lian[2]

To meet the current situation of large extension of corn in the drained paddies under the Rice Crop Substitution Program, a trial on the fertilizer requirements of the crop in the drained paddies was conducted on 16 and 13 locations, respectively in the fall and spring crop seasons during 1983-1985.

The cultivar tested was Tainung No. 351 which is a mid-maturing variety with growth duration of 120-130 days bred for the Program. The locations of the fall crop experiment were mainly distributed in the central and southern parts of the island, while those of the spring crop experiment were distributed in the eastern, northern and central parts of the island; among the locations, two in the central part of the island were conducted with both crops of the experiment. The results are as follows.

1. In the fall crop, the corn responds to N and P in most of the locations, whereas the response to K is smaller in most of the locations. The mean economic rates for N, P_2O_5 and K_2O are 165, 100 and 75 kg/ha, respectively. As the responses to P and K fertilizations are correlated to Olsen P and Mehlich K(or exchangeable K) respectively, the optimum rates for individual soil are recommended according to a soil testing criteria obtained from this study.

2. The yields of the fall crop on these locations ranged 5.0-8.4 t/ha, showing a large variation among the soils. The phosphate fertility as well as physical properties such as compactness of soils are considered as important fertility factors to be studied further.

3. The responses of corn to N P K as well as the yields are significantly lower in the spring than in the fall crop. The mean optimum rates for N, P_2O_5 and K_2O in the spring crop are 100-150, 50-100 and 50 kg/ha, respectively.

4. The Mg concentration in leaves does not correlate with the content of exchangeable Mg in soils, however, it correlates positively with the ratio of exchangeable Mg/K in soils or negatively with the K concentration in leaves.

There were some locations with low ratio of exchangeable Mg/K in soil showing Mg deficiency symptoms in the plant, however, the response to the application of magnesium sulfate was rather limited.

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中華農業（Jour. Agric. Res. China）35(3)：335～349（1986）

石灰質土壤聚積磷素之有效性研究[1]

李子純　吳懷國　陳桂暖[2]

摘要：本研究目的爲明瞭磷肥在石灰質土壤中之有效性及無機磷型態的經時變化，聚積於本省石灰質土壤中磷肥的型態及其有效性，有機物對累積磷素有效性之促進效果，並探討石灰質土壤中有效磷之最佳測定方法。

採取本省中、南部代表性石灰質土壤八種，分別加入0、20及300ppm p 後，置於塑膠罐中，保持田間容水量狀態，以30°C定溫孵育，定期取出測定其有效磷及無機磷型態。同時將此八種土壤，置於溫室，分別加入 300ppm p（均以 $Ca(H_2PO_4)_2 \cdot H_2O$ 溶解後加入）後，連同其對照，保持田間容水量狀態五個月，進行磷聚積處理，處理過的土壤在溫室進行磷肥效應盆栽試驗。盆栽試驗分對照，加磷肥 20ppm p ，及加泥炭 0.8 %三種，作物分別種植玉米及高粱，發芽後約一個月收割，記錄產量，分析其磷含量，計算磷吸收量。有效磷的測定則分別以 Olsen, Bray 及 Modified Bray三種方法進行，結果摘要如下：

1.本試驗中所用土壤有效性磷（Olsen p）含量在 9 至 79 ppm p 之間，平均爲 41ppm p，含量甚高，足見本省石灰質土壤（表土）中聚積的磷肥已甚可觀。

2.在無機磷型態中，原土壤以 H_2SO_4-P 含量最高，NH_4F-P 次之，NaOH-P 最低，各型態所佔之百分率依次爲69,19,及12%。

3.磷肥施入土壤，充分混合，經保持田間容水量狀態五個月後，仍多以 NH_4F-P ，其次爲 NaOH-P型態存在，甚少轉變爲H_2SO_4-P者。

4.土壤加磷後的經時變化測定顯示經加磷 300ppm p 六十天後，有效磷的變化即漸趨平穩，且在本省鈣質土壤中，磷肥施用量在 20～300ppm p 之間時，約爲施用 4ppm p，可提高土壤 Olsen p 1ppm。

5.Olsen, Modified Bray及 Bray 三種方法測得的磷均能有效代表土壤中可被作物吸收的磷，但以前二法略優，又測值之重現性則以Modified Bray法最佳，Olsen 法居次，而以 Bray 法最差。

6.溫室磷肥效應試驗結果顯示，土壤有效磷含量雖高，玉米、高粱仍能因施磷肥而增產，足見石灰質土壤中磷肥的重要性，而施用0.8%的泥炭效果更超過磷肥。

石灰質土壤因pH較高（7.3—8.5）[18]，且含多量（2－3％至60—70%）石灰物質如$CaCO_3$, $MgCO_3$, 或 $CaMg(CO_3)_2$ 等[4]，易與施入土壤中的磷肥作用形成溶解度甚低的磷鈣化含物如DCPD（dicalcium phosphate dihydrate $CaHPO_4 \cdot 2H_2O$), DCP, OCP（octacalcium phosphate $Ca_8H_2(PO_4)_6 \cdot 5H_2O$）或 TCP（tricalcium phosphate）等[17,18,20]，且隨作用時間的延長，更進而形成溶解度更低的 HA（hydroxyapatite), 最後成爲一種幾乎不溶於酸的磷灰石（apatite).[9,20]。

石灰質土壤中磷溶解度低的另一原因係由於 $CaCO_3$ 的存在，$CaCO_3$ 與磷一鈣化合物中鈣的同

1.臺灣省農業試驗所　研究報告第 1292 號。本計畫承農委會資助，報告第一作者受國科會獎助，謹此致謝。
2.本所農化系研究員、助理及約僱技術員。臺灣省　臺中縣　霧峰鄉。

離子效應，使磷鈣化合物的溶解度更降低，此等磷鈣化合物也有以 carbonate-apatite 形態存在者，$CaCO_3$含量愈多，磷溶解度愈小[20]。

由於磷肥在石灰質土壤中形成此等難溶的化合物，使作物不易吸收，故石灰質土壤中的磷肥問題，一向極受重視，而對此方面的研究也較多[5,7,9,13,14,21,24,25]。

本省石灰質土壤農田經長期集約耕作，施用的磷肥必有甚多聚積於土壤中者，雖磷肥在石灰質土壤中的最後產物爲極難溶解的氫氧磷灰石（HA）或磷灰石，但達到此最後階段爲時頗長，且因土壤不同而異[16]，則聚積於本省石灰質土壤中有效磷的含量，其存在的型態，及旱作對磷肥需要的情形等，均爲需要明瞭的問題。又施於石灰質土壤中磷肥有效性的經時變化及如何提高此等聚積於土壤中磷肥的有效性，也爲值得探討的問題。石灰質土壤中有效磷的測定方法，也爲值得探討者，本研究中以三種有效磷測定法作比較，以期選出一較佳的測定方法。

材料與方法

一、土壤：

共用土壤八種，分別採自本省中、南部石灰質土壤地區農田表土（0-15cm），選擇標準爲pH7.3以上，質地均屬中質地，有效磷含量包括中，低及高之範圍，其採取地點及所屬土類列於表 1。

表1. 試驗用土壤之採取地點及所屬土類

Table 1. Sampling locations and soil groups of the experimental soils

土壤	採取地點	所屬土類	土系
1	臺南縣善化鎭 溪美	砂頁岩新冲積土（石灰性）	An（岸內系）
2	臺南縣麻豆鎭 大山	砂頁岩新冲積土（石灰性）	An（岸內系）
3	嘉義縣蒜頭鄉	砂頁岩新冲積土（石灰性）	An（岸內系）
4	彰化縣員林鎭 大明村	粘板岩老冲積土（石灰性）	Eh（二林系）
5	彰化縣大村鄉 橋頭村	粘板岩老冲積土（石灰性）	Eh（二林系）
6	嘉義縣義竹鄉	砂頁岩新冲積土（石灰性）	An（岸內系）
7	彰化縣員林鎭 埔心	粘板岩老冲積土（石灰性）	Eh（二林系）
8	彰化縣員林鎭 大明村	粘板岩老冲積土（石灰性）	Eh（二林系）

二、土壤性質分析：

（一）一般性質：包括土壤 pH（土：水＝1：1），有機質，陽離子交換能量（pH 7.0, 1N NH_4OAC），交換性 Ca, Mg, K，有效性鉀(Mehlich 法)，活性鐵(Asami & Kumada 氏法）及機械分析等。

（二）$CaCO_3$ 含量測定：採酸中和法（Acid-Neutralization method）[6]。

（三）有效磷：共用三種方法測定，即：

1. Olsen法[6]：以 pH8.5, 0.5M $NaHCO_3$ 抽出，土壤與抽出液的比爲 1：20。
2. Bray P-1 法[6]：以 pH3.5, 0.025N HCl-0.03N NH_4F 抽出，土壤與抽出液的比爲 1：10，還原劑用L-ascorbic acid.。
3. Bray P-1 修正法[1]：抽出液與前項同，但土壤與抽出液的比改爲 1：50，其他方法同(2)。

（四）無機磷型態測定：採修正的Chang & Jackson 氏法[23]，唯各型態磷抽出後改以L-asc-

orbic acid 法比色測定，本試驗中僅測定 NH_4F, NaOH, 及 H_2SO_4 抽出部分。

三、有效磷及無機磷型態經時變化測定：

爲明瞭磷肥加入土壤後，其有效性及無機磷型態的變化情形，將定量土壤（100g）置於有蓋塑膠罐內，磷肥加入量分0、20及300ppm P 三等級，以10,000ppm 之 $Ca(H_2PO_4)_2.\ H_2O$溶液加入，磷肥加入後，使罐內之土壤保持田間容水量狀態，不足之水以去礦水加入，置於 30°C 之保溫箱內，定期取出測定其有效磷及不同型態之無機磷含量。爲使土壤與加入之磷肥混合均勻，於加入磷肥一日後，將塑膠罐置於 40°C 之烘箱，開啓罐蓋，使土壤回復風乾狀態，再行磨碎混勻，除取樣作施肥24小時後之有效磷等測定外，其餘土壤重行加水至 Field Capacity 狀態，再行保溫孵育。此後定期測定時，僅取出足够測定之土壤量，于以風乾（40°C），其他土壤則繼續保溫（30°C）孵育。

四、磷聚積處理：

每種土壤各盛 8 盆（每盆13公斤）置於溫室，其中 4 盆爲對照，不加磷肥，另 4 盆各加 300ppm P，以 $Ca(H_2PO_4)_2.\ H_2O$ 溶解後加入，其後即保持田間容水量狀態。各土壤自加水至處理完畢共經150日。

五、溫室磷肥效應試驗：

前項經磷聚積處理過的土壤共16種（8 土壤× 2 處理）進行溫室盆栽試驗，每種土壤再分三處理即：

P_0：僅施 N, K 肥各60及 40ppm. 。

P：除 N, K 外，加施磷肥 20ppm. 。

Peat：除 N, K外，加施 Peat 0.8%，相當於20t/ha. 。

各處理重複三次，共16× 3 × 3 ＝144盆，每盆用土 2kg ，依逢機區集法排列，作物先後種植玉米及高粱（玉米收割後另換新土種植高粱），均爲發芽後約一個月即行收割。

六、植物分析：

作物收割後，以75-80°C 烘乾，秤取其重量，並磨碎經乾灰化後分析其磷含量，以計算磷吸收量。

結果與討論

一、供試土壤性質與有效磷含量（表2）：

（一）土壤一般性質：pH 範圍在7.5至8.0之間，$CaCO_3$ 含量則在 1.95至 4.11%之間，CEC在7.69至 11.30之間，有機質含量在 1.36—5.58%之間，有三個土壤含量在 3 %以上，在本省已屬有機質含量高者，質地則均屬中質地之坋質壤土。

（二）有效磷含量：表 2 顯示三種方法測值中，以 Olsen 氏及修正的 Bray 氏法測值較接近也較高，前者範圍在 9 至89ppm間；後者在12至 101ppm 間，平均則後者高於前者。據美國研究資料 [6、7、24]，土壤 Olsen P 在 10ppm 以上已屬含磷量高者，施磷肥已多無效果，而本試驗所用土壤中僅一個含量爲 9ppm，其他均在 10ppm 以上，有效磷含量應均屬高者。又方氏等 [1] 對甘蔗所定 Modified Bray P 臨界濃度爲 26ppm P，表 2 顯示八土壤中，恰有一半在 26ppm 以下，Bray P 則除 6 號土外，其他均在 20ppm 以下。

二、磷肥在石灰質土壤中有效性的經時變化：

爲明瞭本省石灰質土壤中加入不同量的磷肥後有效性的變化情形，也爲探尋石灰質土壤中磷肥換算指數，或 Griffin & Hanna [11] 所謂的 "Fertilizer equivalent" 即施用若干磷肥，始可提高土壤中有效磷一單位數值（如提高含量 1 ppm P）以三種不同量磷肥（即 0 、20及 300ppm P）加入八種供試土壤中，測定其有效磷含量的經時變化。

圖 1 爲本試驗中所用八種土壤加磷後有效磷的經時變化曲線 。各土壤中變化最大的處理均爲加300ppm P 者，且均在加入後的前十天中降低最快，至60天後即漸趨平穩。在60天時各土壤因施用磷

表2. 土 壤 性 質

Table 2. Soil properties of the experimental soils

Soil No.	pH	O.M. %	CEC me/100	$CaCO_3$ %	Free Fe_2O_3 %	Available P Olsen (ppm)	Available P Bray (ppm)	Available P Modi. Bray (ppm)	Ex. & Soluble Ca (me/100)	Ex. & Soluble Mg (me/100)	Ex. & Soluble K (me/100)	Mehlich K ppm	% Sand	% Clay	% Silt	Texture
1	7.8	2.01	11.20	2.93	1.99	9	0.5	12	12.44	2.63	0.289	100	12.7	24.0	63.2	SiL
2	8.0	1.65	7.83	4.11	1.22	11	3	18	20.45	1.84	0.118	38	13.7	16.0	70.2	SiL
3	7.8	1.87	7.98	1.95	1.09	13	4	20	9.40	1.77	0.166	63	20.1	12.4	67.4	SiL
4	7.6	3.75	9.22	3.96	1.69	39	9	25	27.64	2.39	0.275	77	10.7	26.2	63.0	SiL
5	7.6	5.58	11.30	3.38	1.99	52	9	40	26.50	3.04	0.220	65	11.3	24.2	64.4	SiL
6	7.5	1.36	7.69	3.14	1.40	55	21	95	16.69	2.88	0.389	142	22.7	15.6	61.6	SiL
7	7.6	2.93	8.28	2.30	1.74	69	13	102	9.40	1.80	0.176	61	10.5	27.6	61.8	SiL
8	7.6	3.40	8.28	2.88	1.22	79	13	101	14.22	1.49	0.163	40	22.7	21.2	56.0	SiL
Range	7.5–8.0	1.36–5.58	7.69–11.30	1.95–4.11	1.09–1.99	9–79	0.5–21	12–102	9.40–27.64	1.49–3.04	0.118–0.389	38–142	10.5–22.7	12.4–27.6	56.0–70.2	
Mean	7.15	2.82	8.97	3.08	1.54	41	9	52	17.09	2.23	0.225	73	15.6	20.9	63.5	

肥 300ppm P 而增加的有效磷範圍在 53至 102ppm P 之間，爲原施用量的 18—34 %，八土壤平均爲24%。

各土壤加 20ppm P 的處理中有效磷的變化較平穩，至 60 天時各土壤有效磷含量增加的範圍在 1-8ppm 之間，增加量爲原施用量的 5—40%，八土壤平均爲26%。

由此結果知在鈣質土壤中，磷肥施用量在 20-300ppm P 之間時，約爲施用 4ppm P ，可提高土壤 Olsen P 1ppm，作者過去曾以本省一般土壤作過類似試驗[3]，其結果爲平均施用 3ppm P，可提高 Bray P 1ppm，不同結果應即顯示石灰質土壤之磷肥換算指數較高，但究係由於石灰質土壤中含鈣較多，磷肥施入後，形成的 DCPD 及 DCP 較多，而此等化合物較一般土壤中形成的 Al 、Fe 與磷的化合物難被抽出，抑係其他原因，有待繼續試驗探討。

又圖1顯示八土壤中，未加磷及加 20ppm P 處理之有效磷經時變化以土號1、2及3三含有效磷原低的土壤變化較少，其他五土壤則有較大的起伏，其原因有待探討。

磷肥加入土壤後與土壤的作用曾有不少研究[9,15]，其變化通常均爲開始的數小時（或天）內很快速，然後即隨時間趨於緩和。起初的急速作用被認爲係土壤礦物表面對磷的吸着（True p sorption），其後的緩慢作用則有兩種解釋：其一爲隨作用時間的延長，不同的結晶磷化合物逐漸形成，或者非結晶的化合物轉變爲結晶形態而使其溶解度減低；其二爲被吸着的磷浸入多孔固體內部使土壤表面有更多吸着磷的位置。磷與土壤的作用達於平衡所需時間因土壤種類不同，所含礦物不同，及溫度、水分不同而各異[18,19,20]。有的試驗資料顯示[16]在五年或甚至50至60年後仍未完全平衡。

三、磷肥在石灰質土壤中無機型態的經時變化：

（一）磷肥施用前土壤中無機磷型態分佈：表3爲各土壤無機磷型態原含量，各土壤所含之 H_2SO_4-P（即 Ca-P）均顯著高於NH_4F-P（Al-P）及 NaOH-P（Fe-P）含量，如以八土壤平均計，則 H_2SO_4-P 含量佔三型態磷全量的69%，較過去以本省一般土壤測定結果[3] H_2SO_4-P 量在施肥前佔三型態磷的44%約高一半。按石灰質土壤中，除含有$CaCO_3$外，並含多量的交換性Ca，故土壤中的磷多以不同型態的Ca-P存在[20]。

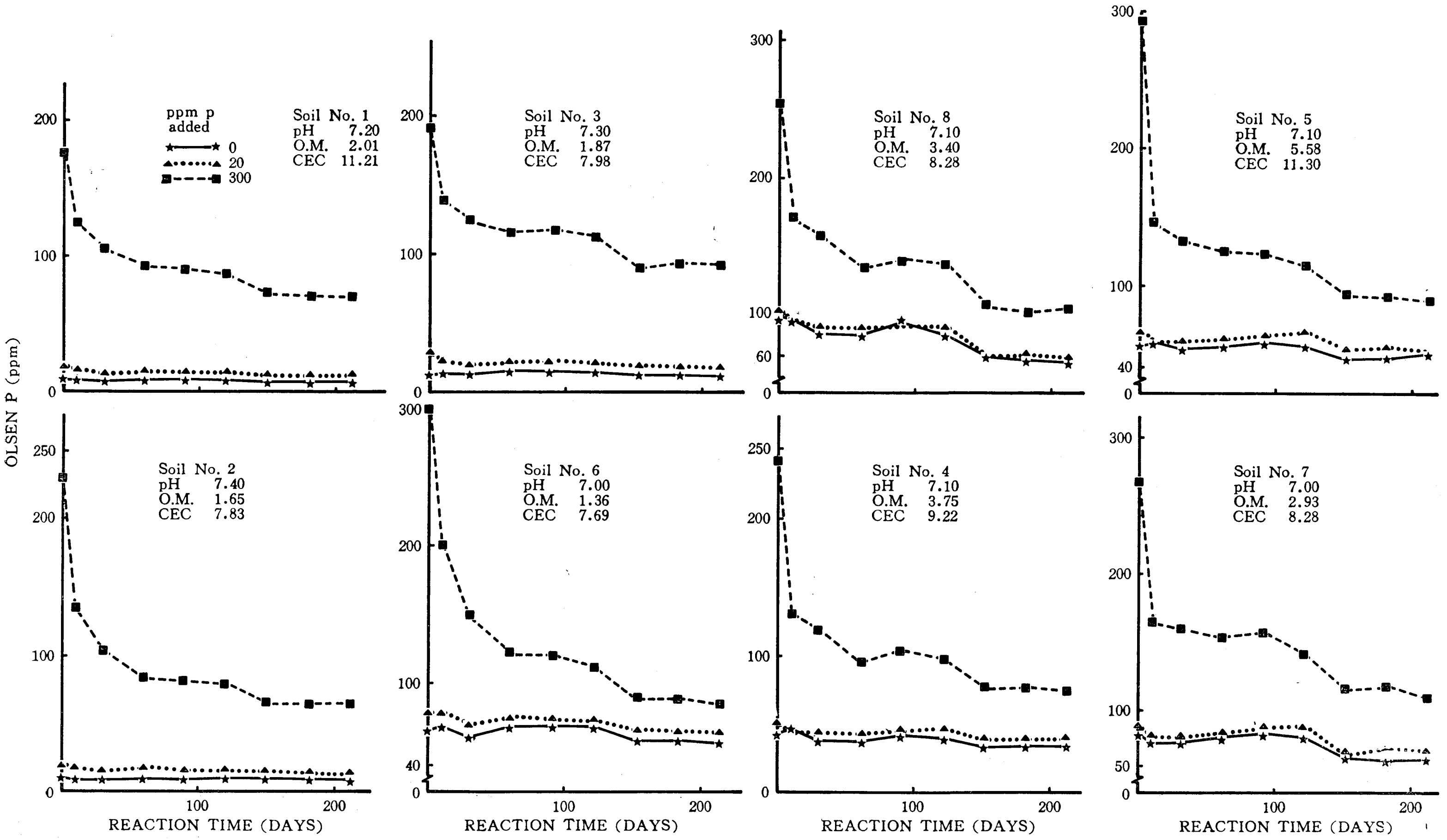


圖1. 土 壤 中 施 磷 後 有 效 磷 的 經 時 變 化

Fig. 1 Available P (Olsen P) values at different periods after phosphorus additions in the laboratory.

表3. 磷肥施用前土壤中無機型態磷 (P ppm) 分佈

Table 3. Inorganic P fractions of the experimental soils before P addition

Soil No. / P fractions	1	2	3	4	5	6	7	8	Range	Mean
NH_4F-P	32	76	47	155	123	202	277	245	32— 277	145
NaOH-P	33	14	39	58	93	60	187	244	14— 244	91
H_2SO_4-P	424	402	298	620	407	509	851	699	298— 851	526
Total	489	492	384	833	623	771	1,315	1,188	384—1,318	

NH_4F-P 及 NaOH-P 之含量在土號 1、3 及 8 三土壤中極爲接近，其他五土壤則 NH_4F-P 均高於 NaOH-P。但含 NH_4F-P 最高的土號 6、7 及 8 三土壤其有效磷含量也爲八土壤中最高者。

(二) 磷肥施用後土壤中無機磷型態分布及經時變化：爲明瞭磷肥施於石灰質土壤後其無機磷型態的變化情形，將前項測定有效磷經時變化的定溫孵育土壤樣本，在加磷 1、90 及 180 日時分別測定其 NH_4F-P, NaOH-P 及 H_2SO_4-P，結果如圖 2 及 3。

此二圖顯示施用 300ppm P 的處理各土壤中均以 NH_4F-P 增加最多，NaOH-P的增加則在土號 1、3、5 及 8 四土壤中較明顯，而 2 號土壤中幾乎無增加。施磷肥 20 ppm P 處理中此二型態磷增加的趨勢與 300ppm P 者相似，僅增加的量極少。H_2SO_4-P 在施用磷肥後的變化不多。

各型態磷在施用後至 180 日間的變化均不多。此項結果顯示在石灰質土壤中施用的磷肥也與其他土壤中一樣，係大部分先以 NH_4F-P，其次以 NaOH-P 型態存在。至施肥半年後，仍極少轉變爲H_2SO_4-P型態者。

按磷肥施入土壤後，遇水逐漸溶解。在其顆粒附近形成各種不同磷化合物，磷肥中成分係以 MCP (monocalcium phosphate) 爲主，由於 MCP本身含多量 Ca^{2+}，足以使溶解而出的磷一半形成溶解度較小的磷鈣化合物如DCPD (dicalcium phosphate dihydrate) 及 DCP (dicalcium phosphate)，在酸性土壤中，另一半的磷即會形成 Fe 或 Al 的化合物；而在鈣質土壤中，由於磷肥溶解處的强酸性 (pH 約在 1.01至1.48 間) 使土壤中的鈣迅即變爲溶解性的 Ca^{2+} 而與絕大部份的磷結合成爲 DCPD 及 DCP[18]，當然同時也有 Al-P 及 Fe-P 形成。Ryan[25] 謂在一些 Fe_2O_3 含量多的土壤中，Ca-P 可能不會成爲主要磷型態。

本試驗中磷肥施用後直至半年時 H_2SO_4-P(即 Ca-P 部份)仍無增加，而僅NH_4F-P 及 NaOH-P 部份增加似不合理。Syers[26] 指出在無機磷型態以修正的 Chang & Jackson 方法 (即本試驗中所採用方法) 分析時，其 NH_4F 抽出部份即含很多 DCPD。由此則本試驗中磷肥加入土壤後半年仍以 NH_4F-P (包括 DCPD) 狀態或 NaOH-P 狀態存在。由原土壤中無機磷型態的分佈以 H_2SO_4-P 所佔比例較大知施入之磷肥在較長時間後始逐漸由DCPD及 DCP 轉變爲其他較難溶解的磷、鈣化合物。

由於上述原因故本報告中將NH_4F 抽出部份的磷以 NH_4F-P 而不以 Al-P 表示，而 NaOH 及 H_2SO_4 抽出部份也同樣以 NaOH-P 及 H_2SO_4-P 表示。

四、溫室磷肥效應試驗：

(一) 溫室磷肥聚積處理：爲明瞭石灰質土壤中累積磷肥的有效性及其型態，除前述保溫孵育分

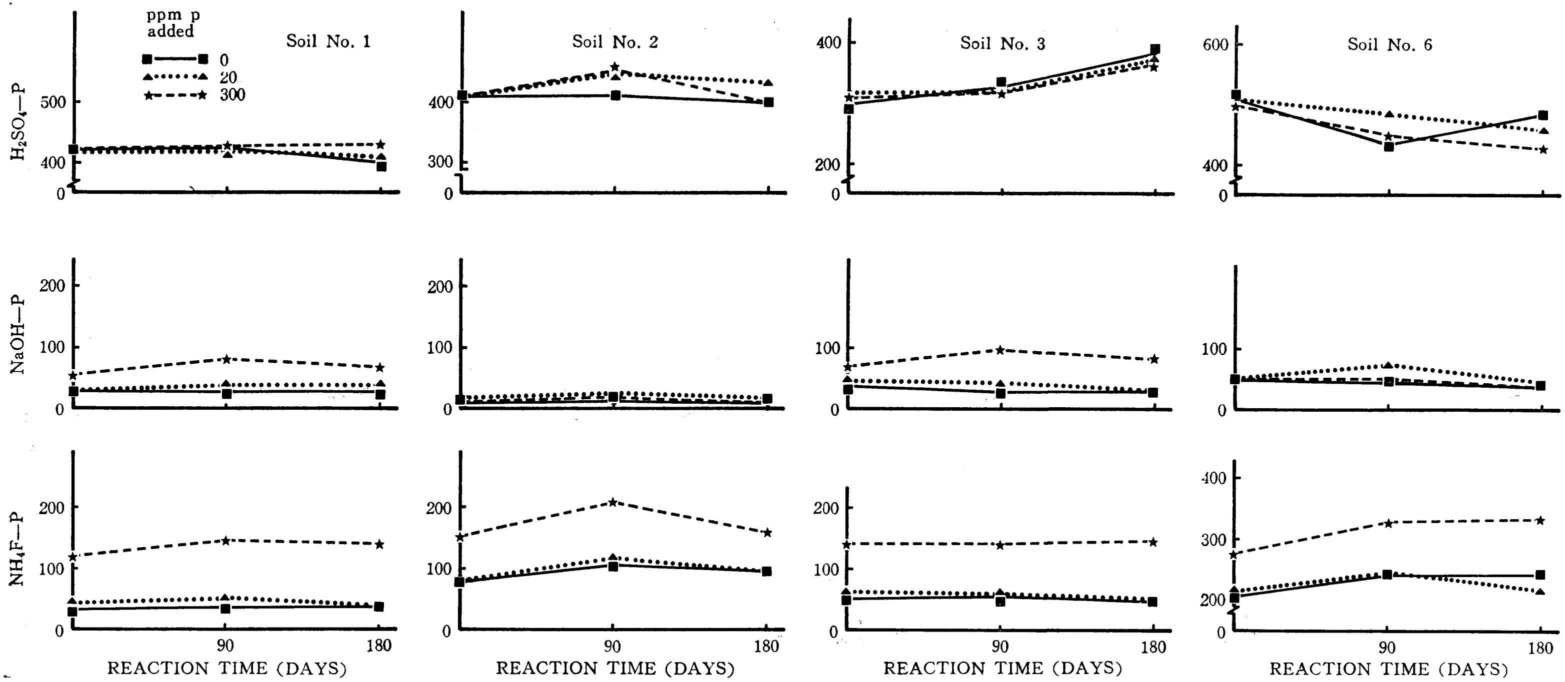


圖2. 土 壤 施 磷 後 無 機 磷 型 態 的 經 時 變 化

Fig. 2. Inorganic P fractions at different periods after phosphorus additions in the laboratory

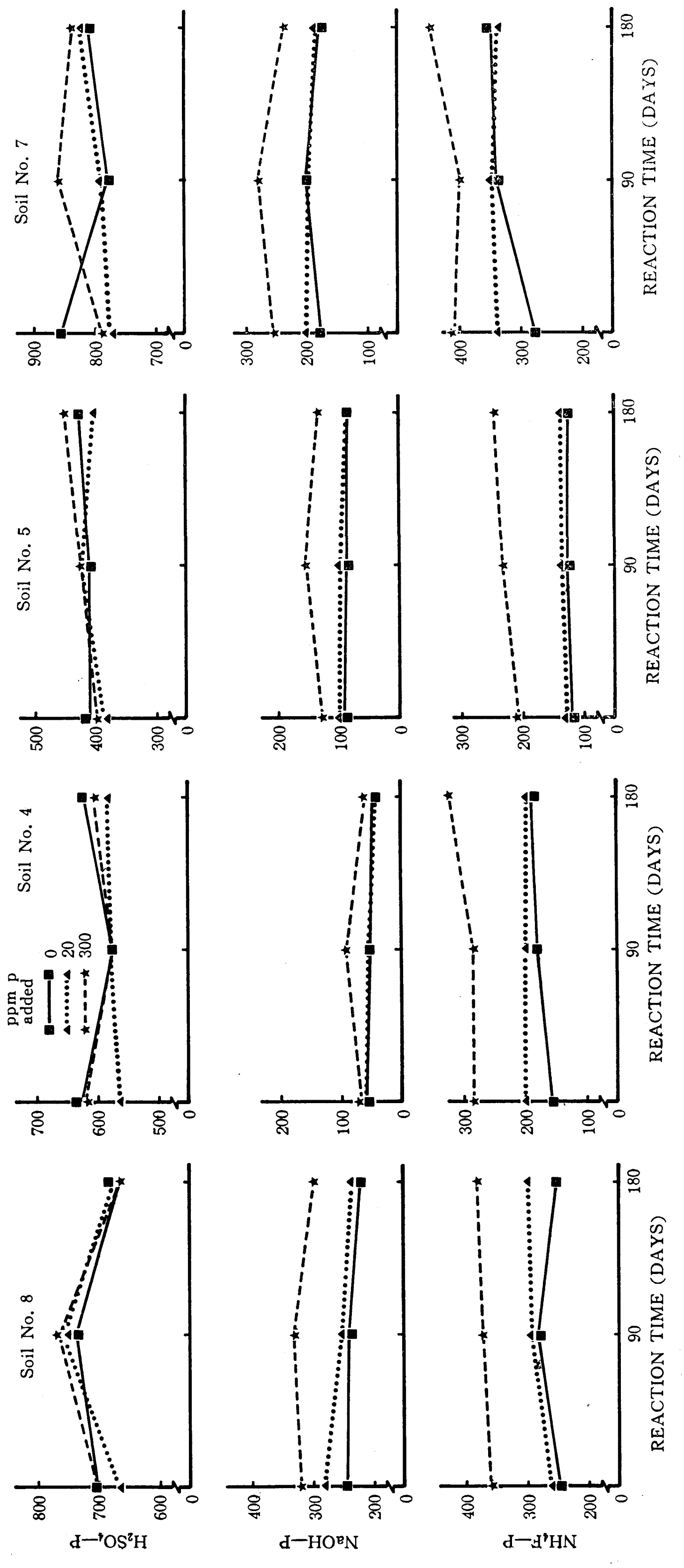


圖3. 土壤施磷後無機磷型態的經時變化

Fig. 3. Inorganic P fractions at different periods after phosphorus additions in the laboratory

析其有效磷及磷型態的經時變化外，同時將八種供試土壤分別加磷肥 300ppm P，並在溫室保持田間容水量狀態共五個月，然後令其風乾，供盆栽試驗用。

此等經磷聚積處理五個月的土壤及各土壤的對照，其有效磷，不同型態磷含量及磷吸着係數列於表4。 此表顯示施磷肥 300ppm P 五個月後土壤中增加者仍爲 NH_4F-P 及 NaOH-P, H_2SO_4-P 增加量極少。趨勢與經時變化測定結果相同（磷吸着係數測定法與過去者[3]同）。

又表4顯示八土壤中的六個均因施磷 300ppm 使其磷吸着係數顯著降低，僅4號及5號土壤降低較少，此二土壤的磷吸着係數原即爲八土壤中最高者，加入 300ppm P 後，兩土壤的磷吸着係數僅降低約 30mg P_2O_5/100g ，（其原吸着係數分別爲 735 及 846mg P_2O_5/100g Soil）。表1之土壤性質顯示此二土壤中 $CaCO_3$及 Clay 含量雖非各土壤中最高者，但其交換性及水溶性鈣含量則居八土壤之首，足見土壤磷吸着受土壤交換性鈣的影響最大。

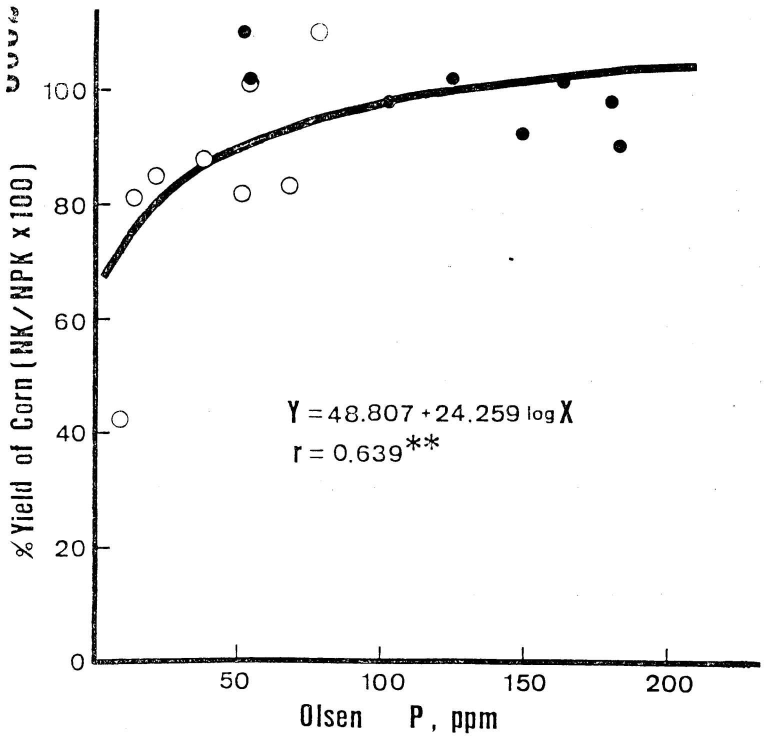
表4. 經溫室磷聚積處理後對照及加磷處理土壤中有效磷、無機磷型態及磷吸着係數的比較

Table 4. Available P, inorganic P fractions and P sorption indices of the experimental soils after P enrichment treatment

P forms / Treat. / Soil No.	Olsan P		Bray P		Modified Bray P		NH_4F-P		NaOH-P		H_2SO_4-P		P sorption mg P_2O_5/100g	
	P_0	P	P_0	P	P_0	P	P_0	P	P_0	P	P_0	P	P_0	P
	ppm													
1	9	52	0.5	30	12	131	33	178	34	83	430	451	413	323
2	11	103	3	34	18	113	79	207	20	24	445	453	423	371
3	13	55	4	47	20	131	47	202	44	95	328	346	415	344
4	39	125	2	9	25	70	238	335	58	84	585	638	735	703
5	52	150	9	15	40	104	128	302	91	156	412	446	846	815
6	55	184	21	64	95	197	118	212	61	66	456	508	495	387
7	69	164	13	44	102	207	465	561	201	243	816	846	455	396
8	79	181	13	36	101	204	356	519	268	392	704	768	573	455
Range	9-79	52-184	0.5-21	2-64	12-102	70-207	33-465	178-561	20-268	24-392	328-816	346-846	413-846	323-815
Mean	41	127	9	34	52	145	183	315	97	143	522	557	540	478

（二）作物磷肥效應：本試驗所用八種土壤經溫室磷聚積處理後連同其對照成爲十六種，各分不加磷肥，加磷肥（20 ppm P） 及加泥炭 （0.8%）等三處理，進行盆栽試驗兩次，種植作物分別爲玉米及高粱，其收量，無磷區收量百分率列於表5。

由表5資料 16 個土壤 Olsen P 含量平均爲 84ppm P， 但無磷區玉米平均收量爲 91.8%；高粱則僅87.1%。圖4及5分別爲無磷區玉米、高粱收量百分率與Olsen P的相關關係及玉米、高粱磷吸收量與Modified Bray P的關係，圖中黑點係經溫室加磷處理過的土壤，白點則爲未加磷的對照。二圖顯示有效磷（Olsen 或 Modified Bray P）與無磷區玉米、高粱收量百分率及其磷吸收量的相關關係均達1%顯著平準，無論磷肥係由五



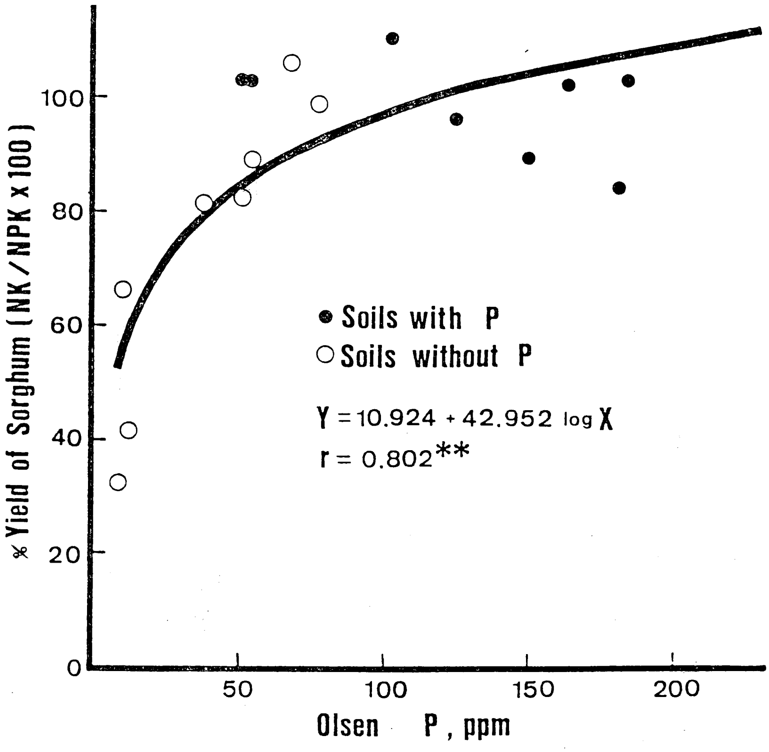


圖4. 無磷區玉米、高粱收量與 Olsen 磷的相關關係

Eig 4. Relationship between Olsen P and relative yield of corn and sorghum

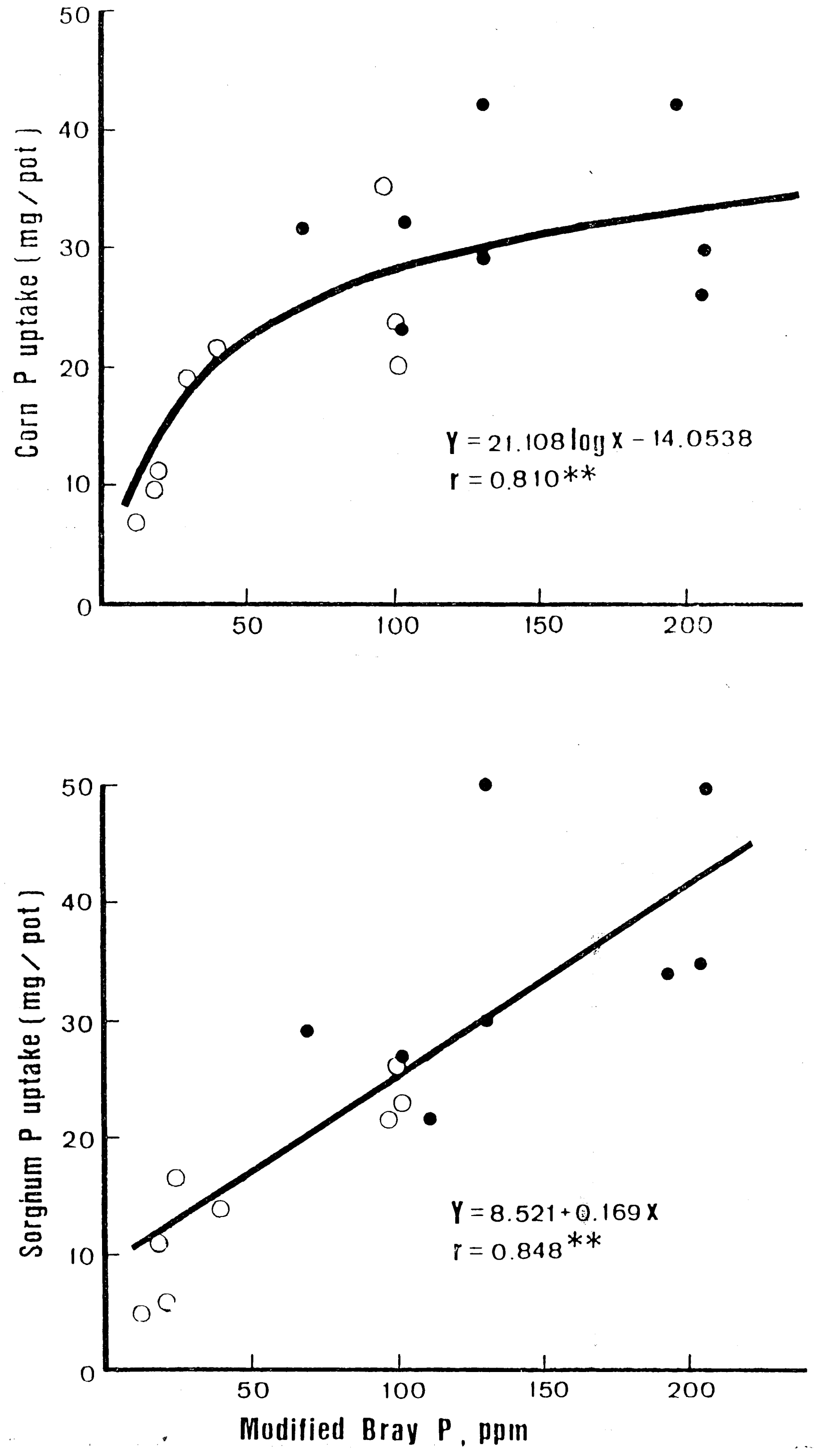


圖5. 作物磷吸收量與修正白雷氏法有效磷的相關關係

Eig 5. Relationship between Modified Bray P and plant P uptaue

個月前的磷聚積處理加入（黑點）或過去加入者（白點）。

圖 4 顯示兩種作物需磷的土壤有效磷臨界濃度遠高於一般的10-15ppm P[7,24]。雖然土壤有效磷的臨界濃度應由進一步的田間試驗訂定，但由此可見石灰質土壤中磷肥對旱作的重要性。

（三）泥炭施用效果：表 5 顯示泥炭在多數土壤中效果均超過磷肥，如以16土壤平均計，則無泥炭區收量百分率（NK/NK+Peat×100%）玉米爲 86.2%，高粱爲 83.7%，較磷肥效果更好。

本試驗中所用泥炭曾以 Olsen 法測定，其含磷量爲 480ppm ，以每盆 2kg 土壤加 16g Peat 計，由 Peat 加入之磷約 8mg P，爲盆栽試驗中磷肥處理之⅕， 但其效果遠高於磷肥。

有機物能促進作物對磷的吸收，其原因爲有機物分解時產生的有機酸（尤以Citrate, Oxalate 及 tartrate 三種最有效）與土壤中的 Ca, Fe，及 Al 等結合而使一些原來溶解度低的磷化含物較易溶解[8,27]，Abbott 等[5]在鈣質土壤中施用 Manure，發現作物含磷量增加，土壤有效磷也因之提高，證實 Manure 確爲極有效的磷素供給源，他們認爲有機物能促進土壤微生物的活動，使磷與土壤中的有機成分結合，此種結合形態作物較易吸收，Lippert的試驗[19]也顯示在鈣質土壤中，Manure所含磷較磷肥更有效。

作者過去曾於磷肥盆栽試驗中加相同的泥炭，而用量爲0.2及0.4%，均對旱作（玉米、高粱）產量無影響，現將用量提高爲 0.8 %始有效果。有機肥料的施用量，似也應作更深入的探討。

六、石灰質土壤有效磷測定方法比較：

爲探討石灰質土壤中有效磷的較佳測定方法，本試驗中土壤有效磷曾以三種方法測定。表 6 爲各有效磷測定法間及各測定法與無機磷型態間的關係，此表顯示 Olsen 氏法與 Bray 氏法間的關係遠遜於其與修正 Bray 氏法者，又 Olsen 氏法與 NH_4F-P 關係最密切，其次爲 NaOH-P， 再次爲 H_2SO_4-P，修正 Bray 氏法與 Olsen 氏法相近，而Bray氏法則與三種型態磷的關係均不顯著。

表6. 不同有效磷測定法及其與無機磷型態間的相關關係

Table 6. Correlation coefficients between soil available P values determined by different extraction methods and inorganic P fraction values

	Bray P	Modified Bray P	NH_4F-P	NaOH-P	H_2SO_4-P
Olsen-P	0.631**	0.768**	0.713**	0.574*	0.520*
Bray-P		0.887**	0.329	0.232	0.124
Modified Bray P			0.656**	0.598*	0.474

* Significant at 5% level; ** Significant at1% level

表 7 爲玉米、高粱無磷區收量百分率，磷吸收量與三種有效磷測值關係的比較。

三種有效磷與兩種作物磷肥效應的曲線關係均已達 1 %顯著程度，且彼此相差不多。作物對磷的吸收量則三種方法中以 Modified Bray 法最優。又經以本試驗中所用土壤以此三種方法重複測定十次的結果（表 8 ），發現以Modified Bray 法重現性最好，其次爲Olsen 法，而以 Bray 法最差。

表7. 玉米、高粱無磷區收量百分率（NK/NPK×100），磷吸收量與不同有效磷測值的關係

Table 7. Correlation coefficients for the relationships between % yield, P uptake of corn, sorghum and the available P values determined by 3 different extraction methods

		Olsen P	Bray P	Modified Bray P	Log Olsen P	Log Bray P	Log Mod. Bray P
% yield of	corn	0.426	0.454	0.556*	0.639**	0.765**	0.727**
	sorghum	0.563*	0.614*	0.671**	0.802**	0.821**	0.845**
P uptake of	Corn	0.615*	0.691**	0.704**	0.748**	0.792**	0.810**
	Sorghum	0.659**	0.704**	0.847**	0.728**	0.776**	0.852**

Modified Bray 法對石灰質土壤中有效磷的測定雖好，但其臨界濃度僅有王氏等 (1) 對甘蔗所訂之26ppm P, 對其他作物究竟如何，應有進一步之試驗探討。

表8. 不同測定法所得有效磷測值及差異係數

Table 8. Range, mean values and coefficients of variation for phosphorus of the experimental soils as determined by three different phosphorus extraction methods

Soil No.	Olsen P Range (ppm)	Olsen P Mean (ppm)	Olsen P C. V. %	Bray P Range (ppm)	Bray P Mean (ppm)	Bray P C. V. %	Modified Bray P Range (ppm)	Modified Bray P Mean (ppm)	Modified Bray P C. V. %
1	6—12	9	17.92	0.3—0.7	0.5	28.20	10— 12	11	5.21
2	9—14	11	15.07	2—4	3	15.71	17— 19	18	4.04
3	11—15	13	11.59	3—5	4	18.94	19— 21	20	3.33
4	34—47	39	10.80	8—12	9	16.84	22— 27	25	6.98
5	49—56	52	6.63	7—13	9	18.14	39— 42	40	2.28
6	50—57	55	4.85	16—28	21	18.44	91—101	95	2.96
7	63—75	69	6.72	12—19	15	13.44	97—106	102	2.90
8	74—86	79	5.43	10—17	13	14.14	95—105	100	3.49
Average		41	9.88		9	17.98		52	3.89

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The Availability and Transformation of Phosphorus Fertilizer in Calcareous Soils of Taiwan[1]

Tze-Shun Lee, Hwai-Gwo Wu and Kuei-Nuan Chen[2]

Summary

Eight calcareous soils ranged from high to low in available P content were collected from central and southern Taiwan for this study. The changes of phosphorus availability as well as its inorganic forms were followed in the laboratory for 200 days when 0, 20, and 300ppm P were added in these soils. A P enrichment treatment was carried out in the greenhouse simultaneously. 300ppm P as monocalcium phosphate were applied in each of these eight soils and kept in field capacity for 5 months. The soils along with their check were then used in a phosphorus response experiment in the greenhouse. Corn and sorghum were planted respectively and the plants were harvested one month after emergence. Dry matter yield and P uptake were recorded. Available P was extracted by three different methods, i. e., Bray, Modified Bray, and Olsen.

The results are summarized as follows.

1. Olsen P ranged from 9 to 79 ppm P with an average of 41 ppm P in these eight soils. High available P indicated there is a high P reserve in our calcareous (surface) soils here in Taiwan.
2. The yield increase of corn and sorghum due to P application in these high P level soils revealed the importance of P fertilization in calcareous soils.
3. The inorganic P fractions of the soils before P enrichment were 69% in H_2SO_4-P, 19% in NH_4F-P, and 12% in NaOH-P.
4. Five months after 300ppm P incorporation, the P was found mostly in the NH_4F-P fraction, followed by NaOH-P, no apparent change was found in the H_2SO_4-P fraction.
5. Available P decreased rapidly during the first 10 days after 300ppm P addition, leveled off after 60 days. As an average, to increase Olsen P 1ppm, 4ppm P should be added in these calcareous soils.
6. High correlations were found between % yield without P, P uptake of corn, sorghum, and P extracted by the three methods used in this study, but the precision of the determination was in decreasing order with Modified Bray, Olsen, and Bray method.
7. The yield response was more prominent when 0.8% peat was applied than phosphate fertilization.

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Purification and Antiserum Preparation of Maize Dwarf Mosaic Virus[1]

T. C. Deng and C. H. Huang[2]

Abstract : A high purity of maize dwarf mosaic virus strain B (MDMV-B) with sufficient yield was obtained by isopycnic centrifugation in cesium sulphate. The virus was infectious and nonaggregated after the purification process. Ultraviolet absorption spectrum of the purified virus showed a typical curve of nucleroprotein with a maximum at 259 and a minimum at 249 nm. The yield of purified virus was 70—80μg per g of tissue. Antiserum to MDMV-B was produced by intramuscular injection of the purified virus to a rabbit. The highest titer of the antiserum obtained 7 weeks after the first injection was 1/8 in SDS-immunodiffusion test, and 1/2048 in precipitin ring test. The completely negative reactions of MDMV-B antiserum to healthy plant extract indicated the efficiency of this method for the purification of MDMV-B. A spur was produced between antigens of an isolate of sugarcane mosaic virus (SCMV) and MDMV-B against antiserum of MDMV-B in SDS-immunodiffusion test. Using the antiserum prepared in this study, we could easily distinguish MDMV-B from strains of SCMV by either SDS-immunodiffusion test or ELISA.

INTRODUCTION

Maize dwarf mosaic (MDM) was first noted as a new disease on corn in Ohio in 1962[10]. The disease was identified to be caused by a maize dwarf mosaic virus (MDMV)[28] or a strain of sugarcane mosaic virus (SCMV)[18] in 1965. Previously, sugarcane mosaic virus strain D (SCMV-D), the most common strain of SCMV on Badila cane, was reported to respond to corn mosaic in Taiwan[23]. However, the occurrence of maize dwarf mosaic virus strain B (MDMV-B) on corn has been reported by Deng[4] recently.

To our knowledge, one reason for the uncertainty in taxonomy of MDMV or SCMV strain was the lack of effective antisera[1,2,14,19,21,27]. Shepherd[18] was the first to purify these viruses, but the titers of antisera prepared by him were 1/256 for SCMV and 1/128 for MDMV in microprecipitin test. To purify those viruses and to prepare

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antisera, various methods were developed [1,2,7,8,9,11,12,14,15,17,19,22,26]. It was possible that the limited yield or the impurity of the purified virus resulted in the low titers or low specificities of antisera. In order to obtain a sufficient purified virus to produce a higher titer of antiserum, a procedure suitable for the purification of MDMV-B was developed in this experiment. This paper presents the results on the purification and antiserum preparation of MDMV-B. Part of the results was published elsewhere [5].

MATERIALS AND METHODS

Source of viruses: The virus for the purification in this study was originally obtained from a naturally infected corn plant in the experimental field of Taiwan Agricultural Research Institute. It was identified as maize dwarf mosaic virus strain B (MDMV-B) on the basis of failing to infect johnsongrass (*Sorghum halepense*) and sugarcane CP 31-294 [4]. Strains of MDMV-B, from infected corn plant in Chiayi, SCMV-B and SCMV-D [7], kindly provided by C. T. Cheng at Taiwan Sugar Research Institute, and S-1 isolate of SCMV, an unidentified strain from infected sugarcane CO 281, were used to compare and test the antiserum of MDMV-B. All virus strains/isolates were maintained on a susceptible corn cultivar Tainan No. 5 by mechanical inoculation in greenhouse.

Purification: Leaf tissues of MDMV-B infected corn plants grown in greenhouse were harvested 2—3 weeks after inoculation and then the midribs were removed. About 200g of leaf tissue was cut into 1cm long and homogenized in a prechilled cold Waring blendor with 300ml of 0.01M phosphate buffer, pH 7.0, containing 0.3% ascorbic acid, 0.01M sodium diethyldithiocarbamate, and 0.3% 2-mercaptoethanol. The homogenate was strained through two layers of cheesecloth, then clarified by adding chloroform with 1ml per 3g leaf tissue. The emulsion was broken by centrifugation at 8,000 rpm for 15min in a Hitachi RPR 12—2 rotor. The supernatant was collected and centrifuged at 30,000 rpm for 90min in a Hitachi RP 50—2 rotor. The resulting pellets were resuspended in 0.05 M borate containing 0.01M Na-EDTA, pH 8.2, and stirred overnight at 4°C. The virus suspension was centrifuged at 8,000 rpm (Hitachi RPR-16 rotor) for 15 min to remove the host components. The supernatant was the partially purified virus.

For further purification, cesium sulphate was added to the virus suspension to make the final concentration of 30 % (w/w), and run at 38,000 rpm for 22—24hr ($w^2t = 1.28 \times 10^{12}$ rad^2/sec) at 6°C in a Hitachi RP-65T rotor. The viral zone was collected from the tube by a small pippet after centrifugation. The purified virus was diluted with equal volume of 0.05M phosphate buffer. Low speed centrifugation was generally proceeded to remove the contaminants. Finally, the virus was dialyzed against the same buffer at 4°C overnight, and concentrated by centrifugation at 30,000 rpm for 90min.

Ultraviolet-absorption spectrum of the purified virus was measured in a dual-beam spectrophotometer (Hitachi 220S). Yield of the virus was estimated by assuming the extinction coefficient of MDMV-B to be 2.4/cm for 0.1% solution at 260nm [20].

Electron microscopy and infectivity test: In some cases, the purified preparations,

after negative staining, were examined with Hitachi H-300 electron microscope. In addition, the purified virus was made with serial dilutions in 0.01M phosphate buffer, and inoculated to 'Tainan No. 5' corn plants for infectivity test.

Production and testing of antiserum: Antiserum to MDMV-B was prepared by intramuscular injection of the purified virus into a rabbit weekly. Initially, 1mg of purified virus in 1ml of phosphate buffer was emulsified with 1ml of Freund's complete adjuvant and then injected. The following 3 injections, 2mg of the purified virus for each , were emulsified with incomplete adjuvant. The rabbit was started to bleed one week after the last injection. All antisera were perserved in the presence of 0.01% sodium azide prior to freezing.

The titers of antisera collected from different times were determined by SDS-immunodiffusion test [16], then the highest one was further checked by precipitin ring test [24]. In SDS-immunodiffusion test, fresh corn leaves infected with MDMV-B were ground in water, then added 3% sodium dodecyl sulfate (SDS). The medium for gel diffusion test consisted of 0.8% Noble agar, 0.5% SDS, 1% sodium azide, and 2% bovine serum albumin (BSA, Sigma Co.) [16]. In precipitin ring test, the purified virus was layered on the tops of serial antiserum dilutions in small tubes [24].

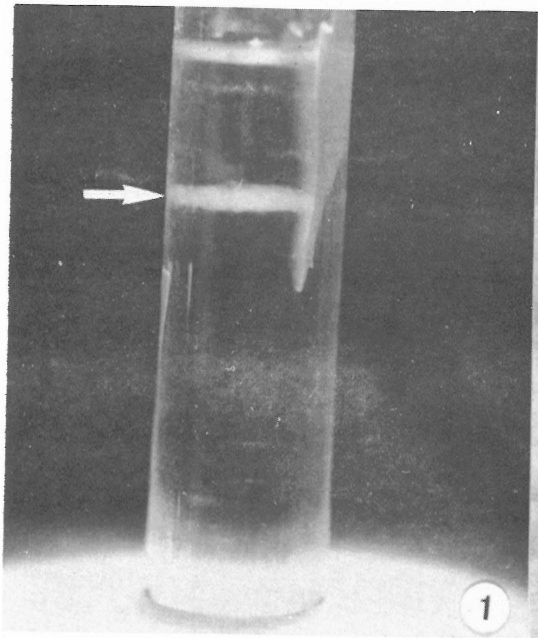
There were two MDMV-B isolates, one SCMV (S-1 isolate) and healthy corn plant for test of MDMV-B antiserum in SDS-immunodiffusion test. However, in addition to above virus isolates, strains of SCMV-B and SCMV-D were involved in enzyme-linked immunosorbent assay (ELISA). The purification and conjugation of immunoglobulin (IgG) with alkaline phosphatase were followed the procedures by Clark and Adams [3], and the double-antibody sandwich (DAS) method was adopted from Voller et al [25].

RESULTS

Purification: Our initial attempts to purify MDMV-B with methods previously described [2,17,18] did not result in satisfactory yield or purity. Because the broad (20mm wide) and ambiguous viral band formed in the tube was difficult to separate virus from plant materials by sucrose density gradient centrifugation. Purification of this virus by CsCl equilibrium centrifugation, a thin viral line was visible in the tube although all contaminants were well separated. Contrarily, the purified virus formed a dense band in Cs_2SO_4 solution after isopycnic centrifugation. In general, the viral band was located at 10—11.5mm below the meniscus and most of plant materials were remained at the top of the Cs_2SO_4 solution after centrifugation. It was easily to remove the purified virus from tubes (Fig. 1).

Ultraviolet absorption: The ultraviolet absorption spectrum of the purified virus as presented in Fig. 3, showed a curve typical for nucleroprotein with a maximum at 259 nm and a minimum at 249nm, but no shoulder at 290nm was observed. The value of A260/280 from several purified prepations ranged from 1.21 to 1.28. Based on the extinction coefficient of 2.4 for a 1-mg/ml solution [20], yield of the purified virus was estimated 70—80μg/g leaf tissue.

Electron microscopy and infectivity test: The purified MDMV-B as observed on



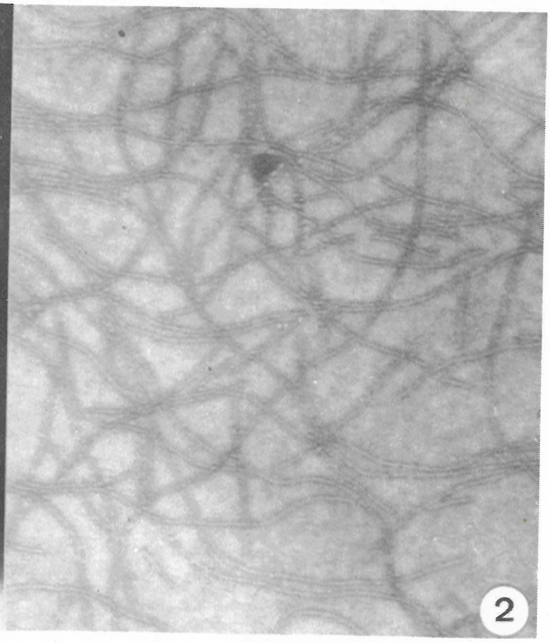


Fig. 1. A visible viral band (arrow indicated) formed 10—11.5mm below meniscus in the tube after centrifugation in cesium sulphate.

Fig. 2. Electron micrography of MDMV-B from purified preparation.

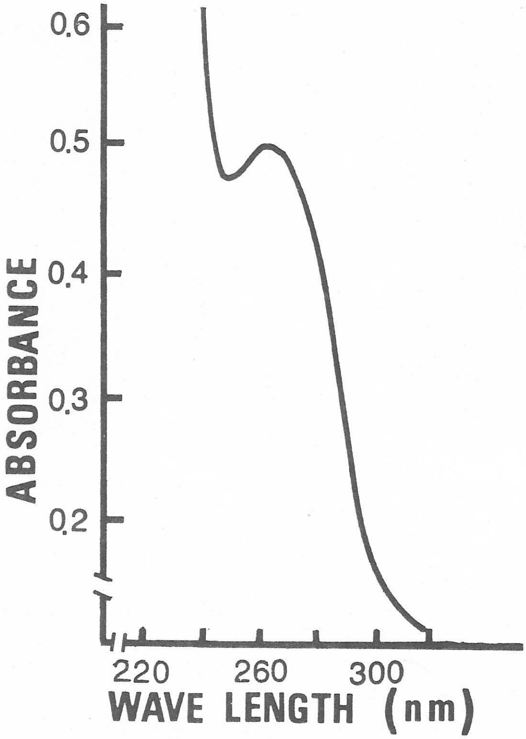


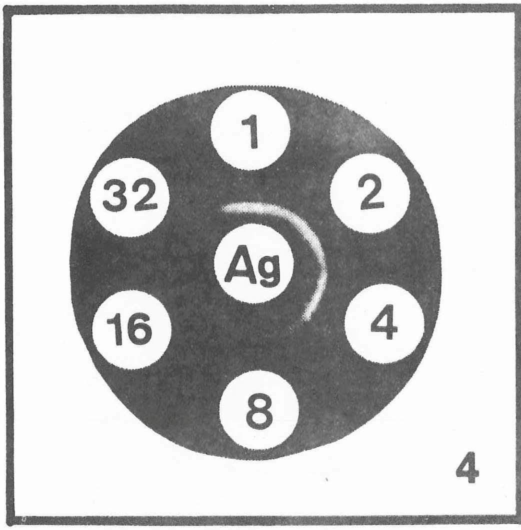
Fig. 3. Ultraviolet absorption spectrum of purified MDMV-B.

electron microscope showed numerous unaggregated filamentous particles (Fig. 2). For infectivity test, the purified preparation of MDMV-B was infectious to corn plants even it was diluted at 1/1280 (mg/ml) in 0.01M phosphate buffer.

Table 1. Reciprocal titers of MDMV-B antisera from six bleedings in SDS-immunodiffusion.

Bleeding of	Reciprocal titer with	
	MDMV-B	Healthy plant sap
1st	4	0
2nd	8	0
3rd	8	0
4th	8	0
5th	4	0
6th	2	0

Titer of antiserum: The immunized rabbit was bled six times totally. The titers of antisera for each bleeding were shown in Table 1 by SDS-immunodiffusion test. The highest one from second bleeding against homologous antigen was 1/8 in SDS-immunodiffusion (Fig. 4), and 1/2048 in precipitin ring test. No reactions were observed when all antisera from six bleedings were tested with healthy plant sap.



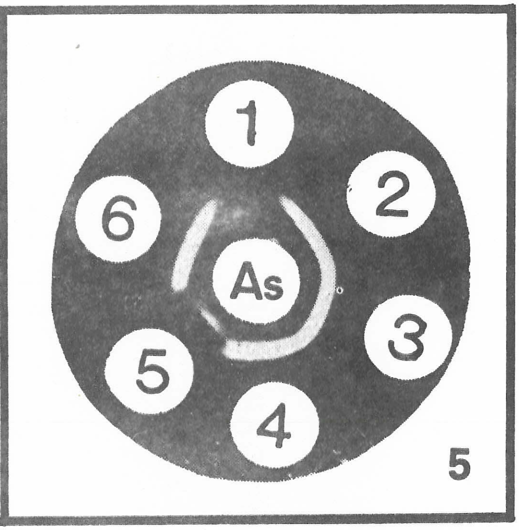


Fig. 4. Precipitation zones resulting from SDS-immunodiffusion test for checking titers of antiserum. The central well contained MDMV-B antigen and the peripheral wells contained serial dilutions of antiserum (numbers are dilution folds).

Fig. 5. Precipitin patterns formed in SDS-immunodiffusion test. The central well was charged with MDMV-B antiserum. The peripheral wells were charged with SDS-treated extracts from healthy corn 'TN 5' (1), MDMV-B infected corn 'TN 5' (2), another isolate of MDMV-B infected corn 'TN 5' (3), MDMV-B infected corn 'TN 351' (4), S-1 isolate of SCMV infected corn 'TN 5' (5), and MDMV-B infected sorghum 'Rio' (6). Spur formed between homologous and heterologous reactions and fused lines formed between homologous reactions.

Testing of antiserum: In SDS-immunodiffusion test, a comparison was made from the reacting patterns of MDMV-B (homologous) and SCMV (heterologous) forming in agar gel. It was clear that a dense precipitation band and a faint line were produced by homologous and heterologous antigens after incubation for 12 hours, respectively. As shown in Fig. 5, a spur was formed after a 2-day-period incubation between two precipitin lines.

In ELISA, the optimum working dilutions were 1μg/ml for coating IgG and 1/1000 for conjugated IgG, and the crude antigens were prepared at 1/10 (w/v) (Table 2). Table 3 showed the results of ELISA for MDMV-B and strains of SCMV. Usually the absorbance of MDMV-B was much higher than those obtained from strains of SCMV. In addition, the low value of the healthy plant sap reacted with MDMV-B antiserum made a clear background in ELISA test. Thus, we could easily distinguish MDMV-B from SCMV strains by this technique.

Table 2. Determination of appropriate working dilutions of reagents for ELISA

Coating IgG (μg/ml)	Dilution of conjugated IgG	Dilution of MDMV-B			Healthy (CK)
		1/10	1/100	1/1000	
2.00	1/500	1.456*	1.180	0.408	0.035
	1/1000	0.736	0.617	0.188	0.006
	1/2000	0.322	0.255	0.080	0.002
1.00	1/500	1.195	0.863	0.289	0.013
	1/1000	0.635	0.432	0.138	0.002
	1/2000	0.226	0.185	0.054	0.003
0.50	1/500	0.524	0.378	0.161	0.021
	1/1000	0.250	0.224	0.080	0.004
	1/200	0.108	0.098	0.033	0.001
0.25	1/200	0.027	0.022	0.000	0.004
	1/400	0.016	0.011	0.001	0.005

* The absorbance values (A_{405nm}) of the reacted substrate were read 30 minutes after incubation at 36°C.

Table 3. Comparison of homologous and heterologous antigens reacted with MDMV-B antibody by ELISA

Antigen	Absorbance at 405nm
MDMV-B	1.699
SCMV-B	0.592
SCMV-D	0.519
S-1 isolate	0.734
Healthy (CK)	0.011
PBS-Tween (blank)	0.000

1) Concentration of coating IgG was made at 1μg/ml, and conjugated IgG was at 1/1000 dilution. The antigens were prepared at 1/10 (w/v) in extraction buffer.
2) The absorbance value (A_{405nm}) of the reacted substrate was read after incubating 60 minutes at 36°C.

DISCUSSION

The problems encountered in purifying MDMV or SCMV are the low concentration in host, instability, and aggregation of the viruses during purification process, and contamination with host proteins in purified preparations (12,14). The method developed in this study seemed satisfactory in purifying maize dwarf mosaic virus strain B.

Zea mays L. 'Golden Cross Bantam' is a very susceptible variety which has been widely used for propagating strains of MDMV and SCMV (1,12,14,18,20). But the rapid decrease of extractable virions 21—28 days after inoculation in this host (13) may be the reason for low yield of the purified virus in previous studies. Since 'Tainan No. 5', a commercial cultivar, is as susceptible as 'Golden Cross Bantam' (4), and it grows more size of leaves in early growing stage, we chose it as the propagative host for our purification studies.

The additions of antioxidants and chelating agents are effective in preventing degradation and aggregation of virus during purification process (20). The unbuffered solution of ascorbic acid, 2-mercaptoethanol, and DIECA had been applied to extract several SCMV and MDMV strains (2,6,10), and the yields of purified virus were much higher than those of virus extracted in 0.5M citrate buffer (19). It is advantageous to keep pH near neutrality throughout the whole purification process, therefore, instead of water, we used 0.01M phosphate buffer for virus extraction. Chloroform has been routinely used for the clarification of corn tissue extract (20), but it reduced the viral infectivity if a higher concentration was applied in the purification of MDMV (8,12,14,19,20). The low concentration of chloroform had been recommended by several workers (22,26), but we obtained a quite infectious purified virus without aggregation when chloroform concentration was added at 1ml per 3g tissue.

Pirone and Aznalone (15) emphasized that all SCMV would lose if a second high speed centrifugation was performed. In our experiment, we still recovered fair amounts

of MDMV-B after two cycles of differential centrifugation. The loss of virus was possibly due to the effects of different buffer systems and/or virus strains. Sucrose density gradient centrifugation had been used conventionally for further purification of MDMV and SCMV [6,12,14,15,18,22], but our results indicated that a broad viral band was formed after centrifugation, and lots of contaminants were collected together. Purification of MDMV and SCMV had been greatly improved by CsCl equilibrium centrifugation [6,8,9,17,26], but Snazell *et al.* [19] found that CsCl or sucrose rate-zonal centrifugation yielded no difference. In this study, the yield of purified virus from Cs_2SO_4 centrifugation was higher than that obtained from CsCl centrifugation indicating that the low pH of CsCl solution may affect the stability of virus during the equilibrium centrifugation, and reduced the yield of purified virus.

Ultraviolet absorption spectrum is a criterion for measuring purity of final sample [6,8,12,,14,17,22,26]. Pirone and Anzalone [15] could not obtain a typical spectrum of purified SCMV although little extraneous material was visible in the EM. Our initial trial showed that there was no typical UV-absorption curve when the virus was purified by sucrose density gradient centrifugation. However, the virus purified by Cs_2SO_4 centrifugation, the typical curve for nucleroprotein was obtained. The slight shoulder of UV absorption spectrum at 290nm or 288nm was not observed in our study although it was reported by many authors [8,12,14,26]. Anyway, our result agreed to the report of Sehgal and Jean [17]. The value of A260/280 ranged from 1.21 to 1.28 and the yield of purified virus about 70—80 μg/g leaf tissue as comparing to the other reports [2,6,8,9,11,12,14,17,21,26], it seems that we have improved the method in purification of MDMV-B.

Previously, microprecipitin test was used to serotype the strains of MDMV and SCMV [1,2,7,11,18,19,21,26,27], but MDMV-B, SCMV-B, or SCMV-D were serologically indistinguishable in those reports [11,21]. The MDMV-B antiserum as prepared in this experiment produced a dense preciptin line with its homologous antigen and formed spurred reactions with its heterologous antigens in SDS-immunodiffusion tests suggesting that this antiserum can be used to differentiate MDMV-B from SCMV strains. Details for comparison among strains of MDMV and SCMV, and field studies are in progress.

ACKNOWLEDGEMENTS

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玉米矮化嵌紋病毒之純化與抗血清製作[1]

鄧 汀 欽 黃 秋 雄[2]

摘 要

利用等密度平衡離心法純化玉米矮化嵌紋病毒 B 型系統，以提高病毒純度及產量。純化所得之MDMV-B 仍具相當之感染力，且純化過程並無病毒聚集現象。以紫外光吸收光譜測定病毒純度，可得一標準的核蛋白吸收曲線，其最高值在259nm最低值在249nm。純化的病毒產量為每克葉片有70—80微克。利用純化的MDMV-B 對白兎行肌肉注射以製作抗血清，其力價以瓊脂擴散反應測定最高為1/8，但以沈澱環反應測定則為 1/2048。此等抗血清完全不與健康的玉米株汁液反應，可見利用本方法已獲得良好純化效果。從甘蔗分離出來而在玉米上繁殖的一個甘蔗嵌紋病毒系統與MDMV-B 抗血清有反應，但是在瓊脂擴散反應試驗時形成刺狀沈澱帶，由此可以區分MDMV-B和本省之SCMV 系統。另由酵素結合抗體免疫分析的結果，MDMV-B、SCMV-B及SCMV-D對 MDMV-B 抗體反應的讀值，同樣可以確認其間的異同。

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穀類害蟲燻煙防治研究[1]

林 檥[2]

摘要：在中南部選擇水泥磚造倉庫；空倉放置墊倉穀殼者三處，貯藏袋裝稻穀者三處，袋裝玉米及高粱各二處。以 Baythion 0.5g (AI)/M^3 與 Phostoxin 以 3 片／M^3 藥量防治害蟲，前者密閉燻煙 2 天，後者燻蒸 5 天。處理後空倉及穀殼各採樣一次，袋裝稻穀貯藏 4 及 6 個月，袋裝玉米貯藏 2 個月，袋裝高粱貯藏 3 個月，於每月採樣一次。用 Baythion 燻煙法對空倉昆蟲20種，墊倉穀殼昆蟲11種，及袋裝穀類昆蟲15種均可全部殺死，此方法可達到經濟有效治蟲效果。Phostoxin 僅作爲緊急燻蒸處理，效果雖佳，但因無殘效性，價格又昂貴，故燻蒸後再用 Baythion 燻煙處理，治蟲更能徹底，且較經濟。

以六種藥劑用燻煙法處理麻布測定其殘留毒效，其中 Actellic, Baythion, Dursban, Elsan 四種可維持 5 個月以上，而 Phosdrin 及 Nexion 則能維持 4 個月左右。

爲減輕倉儲穀類受蟲害之損失，現行積穀蟲害防治分爲空倉消毒及穀堆表面撒佈粉劑等方法。害蟲大量發生需要緊急處理時，則採用燻蒸措施。往往由於農忙，未能徹底執行一般防治，又燻蒸方法較不經濟。近年來稻穀貯藏方式改爲袋裝，蟲害程度顯較散裝者爲嚴重，除密閉倉庫可採用燻蒸外，其餘多數倉庫則無適當之防治方法。有鑑於此，經在室內及倉庫實地進行藥劑燻煙試驗，治蟲效果甚優且較徹底。爲擴大地區探究藥劑燻煙處理之治蟲效果，並與好達勝燻蒸處理之效益進行評估，茲將所獲結果報告於後。

材料與方法

一、倉庫試驗

試驗地點：在臺中縣清水鎮、外埔鄉，彰化市，南投縣名間鄉、新街辦事處等農會倉庫，進行空倉，墊倉穀殼及袋裝稻穀之燻煙與燻蒸試驗。臺南縣學甲鎮及歸仁鄉農會袋裝玉米倉庫及嘉義縣義竹鄉農會袋裝高粱倉庫燻煙及燻蒸處理試驗。

使用藥劑及用量：Baythion 10% (o, o-Diethyl-phosphorothioate-o-ester of Phenyl-glyoxylicnitrile-oxime) 係興農股份有限公司出品，用藥量以 0.5g (AI)/M^3 燻煙。Phostoxin 55% (Aluminum Phosphide) 係西德 (Degesch) 公司出品，其用藥量以 3 片/M^3燻蒸。

噴煙之器械：採用煙霧機 (DYNA-FOG "DH 90 B") 爲美國製金鷹牌，將藥液經此機械以高壓噴出，成煙霧狀。

防治方法

1.空倉燻煙處理：選擇試驗倉庫後在試驗前 5 天，先行地面掃除雜物及害蟲屍體，以免干擾日後取樣之誤差。試驗時將墊倉穀殼先搬放倉內中央，然後將所有窗門全部關閉，僅留一倉門以塑膠布封閉，在距離地面約 30cm處剪成直徑 7cm 小孔，俾供煙霧機插入噴煙之用；通氣孔則張掛麻袋以防煙霧外洩，噴煙後立即關閉倉門，三倉庫即爲三重複處理，另三倉庫未施藥作爲對照。

1.臺灣省農業試驗所 研究報告第1294號。本研究承行政院農業發展委員會中央加速農村建設 (73農建—4.1—產—23 (2) 計畫補助經費完成。

2.本所應用動物系助理。臺灣省 臺中縣 霧峰鄉。

2.袋裝穀物燻蒸與燻煙處理：貯藏袋裝稻穀及玉米、高粱倉庫試驗時，將所有倉門、窗等關密後並用牛皮紙封閉，僅留一倉門供投藥人員出入，在倉庫外啓開藥罐，將所需燻蒸藥量携入倉內，經均勻投藥後即關閉倉門，並用牛皮紙密封。經燻蒸 5 天後開倉。如燻蒸後再噴煙處理者，則以上述空倉燻煙方法，在倉庫燻蒸 5 天後用噴煙機噴煙處理，隨即關閉倉門。經燻煙 2 天後開倉。各二倉庫即爲二重複處理。另二倉庫未施藥作爲對照。

防治前後採樣：空倉燻煙處理前後在同一位置掃集墻脚地面 $1M^2$所有雜物與昆蟲，五重複。同時採取墊倉穀殼1ℓ，放入塑膠袋携回檢查，三重複。袋裝稻穀及玉米、高粱採樣於處理前及處理後堆頂袋表面同一位置，掃集 25×25cm範圍內所有害蟲放入塑膠袋，五重複，並自袋中採取樣品 1kg放入細布袋，三重複。以後每月採樣一次。

樣品檢查：將樣品倒於不銹鋼篩篩出所有害蟲，分別檢查害蟲種類及每種害蟲之活存與死蟲數，並以量筒盛穀物100ml秤重量及取穀物 1g測定含水量，五重複，以計算蟲害損失率。

二、室內試驗

供試藥劑及其用藥量：Actellic 90% (o, o-Dimethyl-o-(2-diethylamino-4-methylpyrimidin-6-yl) phosphorothioate or 2-Diethyl amino-6-methylpyrimidin-4-yl-dimethyl phosphorothioate) (英商卜內門公司) 。Baythion 84.5% (興農股份有限公司) 。 Dursban 99% (o, o-Diethyl-o-3, 5, 6-trichloro-2-pyridyl phosphorothioate.) (惠光化學有限公司) 。Nexion 90% (o, o-Dimethyl-o-2, 5-dichloro-4-bromophenyl-thionophosphate) (正光化工股份有限公司) Elsan 92% (Ethyl-(o, o-dimethyl)-dithiophosphoryl-1-phenylacetate or o, o-Dimethyl-S-(a-ethoxy carbonyl benzyl)-phosphorodithioate) Phosdrin 100% (1-Carbomethoxy-1-propen-2-yl-o, o-dimethyl phosphate) (省農會農化廠) 。各以 0.5、0.3及0.1g (AI)/M^3 用量。

試驗方法：將蔴布剪成 10×10cm，放入玻璃密器內， 以上述藥劑規定用藥量燻煙處理後，經 4 小時取出蔴布放置木箱 60×70×25cm 內稻米表面，箱內繁殖米象 (*Sitophilus oryzae*) 玉米象 (*Sitophilus zeamais*) 、穀蠹 (*Rhizopertha dominica*) 、擬穀盜 (*Tribolium castaneum*) 及小紅鰹節蟲 (*Trogoderma granarium*) 等，任其自由爬行接觸，各五重複。另設一未施藥供作對照。

藥效檢查：每隔10天取出蔴布檢查兩面之存活與死蟲數，檢查後蔴布再放回木箱內，視其藥效消降，以確定藥效持久性。

結 果

一、倉庫試驗

在空倉及墊倉穀殼，以 Baythion 燻煙處理，空倉燻煙之結果死亡落地蟲數爲無施藥對照倉庫之三倍以上，可見倉內壁縫隙潛伏着許多害蟲，其防治率可達到 100%。而對穀殼中含蟲之防治效果亦

表 1. Baythion 燻煙處理空倉及穀殼之治蟲效果

Table 1. Effect of smoking with baythion on the control of insects on husks or empty warehouse

用藥量 Dosage g(AI)/M^3	空倉 Empty Warehouse			穀殼 husks		
	處理前蟲數(活蟲率) Pre-treatment no. insects (Survival rates)	處理後蟲數(活蟲率) Post-treatment no. insects (Survival rates)	防治率% of effectireness	處理前蟲數(活蟲率) Pre-treatment no. insects (Survival rates)	處理後蟲數(活蟲率) Post-treatment no. insects (Survival rates)	防治率% of effectireness
0.5	211.3 (8.9)	375.5 (0)	100	37.1 (5.9)	37.8 (2.1)	80.9
0 (CK)	141.6 (6.6)	113.2 (4.5)	0	66.0 (11.0)	66.0 (11.0)	0

表 2. Baythion 燻煙處理空倉及穀殼中害蟲發生密度

Table 2. No. of insects found in empty warehouse and husks after smoking with baythion

用藥量 Dosage g(AI)/M³	檢查期間(月) Time of Examination (month)	*Sitophilus oryzae*	*Sitophilus zeamais*	*Rhizopertha dominica*	*Tribolium castaneum*	*Gnathocerus maxillosus*	*Latheticus oryzae*	*Alphitobius diaperinus*	*Tenebroides mauritanicus*	*Lophocateres pusillus*	*Oryzaephilus surinamensis*	*Cryptolestes ferrugineus*	*Trogoderma granarium*	*Sitotroga cerealella*	Other[1]
空倉潛伏害蟲 Empty warehouse															
0.5	處理前 Pre-treatment	11.6	0.1	109.4	7.6	1.1	3.1	1.3	0.1	30.0	28.3	8.3	0.1	1.5	8.8
	處理後[2] Post-treatment	29.2	0	199.0	11.2	4.3	2.2	4.2	0.3	27.1	8.1	5.8	0.2	3.9	80.0
	合計 Total	40.8	0.1	308.4	18.8	5.4	5.3	5.5	0.4	57.1	36.4	14.1	0.3	5.4	88.8
	比率 Raet	6.9	0.1	52.5	3.2	0.9	0.9	0.9	0.1	9.7	6.2	2.4	0.1	0.9	15.2
0 (CK)	處理前 Pre-treatment	3.2	0	53.6	5.2	3.5	1.0	0.5	0	30.8	8.4	31.8	0.1	0.8	2.7
	處理後[2] Post-treatment	4.5	0.3	76.8	3.0	1.0	1.1	0.1	0.5	6.7	8.8	4.3	0.5	0.2	5.4
	合計 Total	7.7	0.3	130.4	8.2	4.5	2.1	0.6	0.5	37.5	17.2	36.1	0.6	1.0	8.1
	比率 Rate	3.0	0.1	51.2	3.2	1.7	0.8	0.2	0.2	14.7	6.8	14.2	0.2	0.4	3.3
穀殼內含蟲 Husks															
0.5	處理前 Pre-treatment	0.4	0	32.0	0	0	0.5	0	0	1.7	1.8	0.7	0	0	0
	處理後[2] Post-treatment	2.2	0	30.9	0.1	0.2	0.2	0	0	0.7	1.1	1.9	0	0	0.5
	合計 Total	2.6	0	62.9	0.1	0.2	0.7	0	0	2.4	2.9	2.6	0	0	0.5
	比率 Rate	3.5	0	83.9	0.1	0.3	0.9	0	0	3.2	3.9	3.5	0	0	0.7
0 (CK)	處理前 Pre-treatment	4.0	0	53.0	3.3	0	0	0.3	0	1.3	1.0	2.4	0.7	0	0
	處理後[2] Post-treatment	4.0	0	53.0	3.3	0	0	0.3	0	1.3	1.0	2.4	0.7	0	0
	合計 Total	8.0	0	106.0	6.6	0	0	0.6	0	2.6	2.0	4.8	1.4	0	0
	比率 Rate	6.0	0	80.3	5.0	0	0	0.5	0	1.9	1.6	3.6	1.1	0	0

1.其他包括大擬穀盜、矮圓細肩蟲、矮毛鰹節蟲、背圓標本蟲、細豆蟲、粉斑螟蛾、椿象、蜚蠊、僞蠍、蜘蛛 (Others: including *Palorus foveicollis Murmidius, ovalis. Trinodes rufescens, Gibbium psyllioides, Thorictodes heydeni, Ephestia cautella*, Reduviid bugs, Minute pirate bug, Cockroach, Pseudoscorphions and Spiders).

2.燻煙處理後經 2 天 (2 days after treatment).

能達80%以上（表1）。在空倉中採樣檢查得知發生害蟲共有20種；其發生相對密度，在施藥組與對照組均以穀蠹最高分別 52.5；51.2%，暹羅穀盜（*Lophocateres pusillus*）9.7；14.7%，角胸粉扁蟲（*Cryptolestes ferrugineus*）2.4；14.2%，鋸胸粉扁蟲（*Oryzaphilus surinamensis*）6.2；6.8%，米象 6.9；3.0%，擬穀盜 3.2；3.2%，細擬穀盜（*Gnathocerus maxillosus*）0.9；1.7%，長首穀盜（*Latheticus oryzae*）0.9；0.8%，麥蛾（*Sitotroga cerealella*）0.9；0.4%，外米僞步行蟲（*Alphitobius diaperinus*）0.9；0.3%，大穀盜（*Tenebroides mauritanicus*）0.1；0.2%，小紅鰹節蟲0.1；0.2%，玉米象0.1；0.1%，其他包括大擬穀盜（*Palorus foveicollis*），矮圓細肩蟲（*Murmidius ovalis*），矮毛鰹節蟲（*Trinodes rufescens*），背圓標本蟲（*Cibbium psyllioides*），細豆蟲（*Thorictodes heydeni*），粉斑螟蛾（*Ephestia cautella*），椿象（*Reduviid bugs*）、（*Minute pirate bug*），蜚蠊（*Cockroach*），僞蠍（*Pseudoscorpions*），蜘蛛（*Spiders*）合計爲 15.2；3.3%。穀殼中含蟲11種；其相對密度，穀蠹爲83.9；80.3%，米象 3.5；6.0%，角胸粉扁蟲 3.5；3.6%，鋸胸粉扁蟲3.9；1.6%，暹羅穀盜3.2；1.9%，擬穀盜0.1；5.0%，小紅鰹節蟲0；1.1%，長首穀盜0.9；0%，外米僞步行蟲0；0.5%，細擬穀盜0.3；0%，其他包括細豆蟲，僞蠍合計爲 0.7；0%。（表2）。另有壁虎、老鼠之死亡數尚未列入。

表 3. Baythion 燻煙處理袋裝稻穀之治蟲效果

Table 3. Effect of smoking with baythion on the control of insects of bagged rice

用藥量 Dosage g(AI)/M³	檢查期間(月) Time of Examination (month)	袋表面 Bag surface			袋中稻穀 Rice in bag				
		蟲數 insects	活蟲率 Percentage of livingi-nscts	防治率% of effectiveness	蟲數 insects	活蟲率 Percentage of livinginscts	防治率% of effectiveness	損失量 Loss	減少損失率 Reduced loss rate
0.5	處理前 Pre-treatment	4.7	2.1	—	0	0	—	—	—
	處理後[1] Post-treatment	6.7	0	100.0	0	0	0	0	0
	1	1.7	0	100.0	0	0	0	0	0
	2	30.5	0.7	77.4	62.7	15.9	51.4	0.2	0.1
	3	15.1	0	100.0	96.2	22.9	38.8	0.2	0.1
	4	12.0	0	100.0	118.7	16.3	51.8	0.3	0.3
	5	19.2	0.6	97.7	104.4	18.9	46.0	0.3	0.6
	6	14.2	0.7	97.8	151.7	16.5	60.7	0.4	0.7
0 (CK)	處理前 Pre-treatment	2.9	3.4	—	0	0	—	—	
	處理後[1] Post-treatment	7.4	1.4	0	0	0	0	0	
	1	3.0	100.0	0	0	0	0	0	
	2	12.7	3.1	0	39.7	32.7	0	0.3	
	3	8.1	1.2	0	107.0	37.4	0	0.3	
	4	7.7	3.9	0	165.5	33.8	0	0.6	
	5	23.4	25.6	0	213.0	35.0	0	0.9	
	6	35.6	31.7	0	326.3	42.0	0	1.1	

1.燻煙處理後經2天 (2 days after treatment).

表 4. Baythion 燻煙處理袋裝稻穀之害蟲發生密度

Table 4. No. of insects found on bagged rice after treatment smoking baythion

用藥量 Dosage g(AI)/M³	檢查期間(月) Time of Examination (month)	*Sitophilus oryzae*		*Sitophilus zeamais*		*Rhizopertha dominica*		*Tribolium castaneum*		*Gnathocerus maxillosus*		*Latheticus oryzae*	
		Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag
0.5	處理前 Pre-treatment	0.1	0	0	0	3.9	0	0.1	0	0	0	0	0
	處理後[2] Post-treatment	0	0	0	0	5.5	0	0.8	0	0	0	0	0
	1	0.3	0	0	0	0.7	0	0.4	0	0	0	0	0
	2	0.1	0.3	0	0.1	24.6	53.6	2.0	4.7	0.1	0	0.1	0.1
	3	0.1	0.2	0	0	13.5	86.6	0.5	6.1	0	0.2	0.2	0.1
	4	0.1	0.2	0	0.2	10.7	107.0	0.4	7.2	0	0.1	0.2	0.5
	5	2.0	0.1	0	0.1	13.5	91.5	1.3	9.1	0	0	0.1	0.4
	6	0	0.1	0	0	11.7	136.7	0.3	9.7	0	0	0.2	0.8
	合計 Total	2.7	0.9	0	0.4	84.1	475.4	5.8	36.8	0.1	0.3	0.8	1.9
	比率 Rate	2.6	0.1	0	0.1	80.8	89.1	5.6	6.9	0.1	0.1	0.7	0.3
0 (CK)	處理前 Pre-treatment	0.1	0	0	0	2.3	0	0.3	0	0	0	0	0
	處理後[2] Post-treatment	0.1	0	0	0	6.8	0	0.1	0	0	0	0	0
	1	0.4	0	0	0	1.5	0	0.3	0	0	0	0	0
	2	0	0	0	0.1	10.1	29.6	1.2	4.6	0	0	0.5	0
	3	0	3.8	0	0	7.0	90.0	0.3	6.3	0	0	0	0
	4	0.1	5.6	0	0	5.9	125.0	1.0	15.5	0	0	0	0.2
	5	1.0	10.3	0	0	15.5	148.1	4.2	20.9	0	0	0	1.0
	6	1.1	20.7	0	0	22.7	212.0	8.7	32.0	0	0	0	3.0
	合計 Total	2.8	40.4	0	0.1	71.8	604.7	16.1	79.3	0	0	0.5	4.2
	比率 Rate	2.8	4.7	0	0.1	71.2	71.0	16.0	9.3	0	0	0.5	0.5

1.其他包括矮毛鰹節蟲、椿象、蜘蛛 (Others: including *Trinodes rufescens* Reduviid bugs, Minute pirate bug and Spiders).

2.燻煙處理後經2天 (2 days after treatment).

續表 4. (Continued table 4.)

用藥量 Dosage g(AI)/M³	檢查間期(月) Time of Examination (month)	*Lophocateres pusillus*		*Oryzaephilus surinamensis*		*Cryptolestes ferrugineus*		*Trogoderma granarium*		*Sitotroga cerealella*		Other¹	
		Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag
0.5	處理前 Pre-treatment	0.2	0	0.1	0	0.1	0	0.1	0	0	0	0.1	0
	處理後² Pact-treatment	0	0	0.1	0	0.1	0	0.1	0	0.1	0	0.1	0
	1	0.2	0	0	0	0	0	0	0	0	0	0	0
	2	0.1	1.1	0.6	0.7	0.8	1.0	0	0	0.1	0	2.0	1.1
	3	0.1	0.6	0.5	0.8	0.2	0.6	0	0	0	0	0	1.0
	4	0	1.6	0.2	1.2	0.4	0.7	0	0	0	0	0	0
	5	0	0.5	0.9	0.6	1.4	2.1	0	0	0	0	0	0
	6	0	0.9	0.5	1.6	1.5	1.7	0	0	0	0.2	0	0
	合計 Total	0.6	4.7	2.9	4.9	4.5	6.1	0.2	0	0.2	0.2	2.2	2.1
	比率 Rate	0.6	0.9	2.8	0.9	4.3	1.1	0.2	0	0.2	0.1	2.1	0.4
0 (CK)	處理前 Pre-treatment	0.1	0	0.1	0	0	0	0	0	0	0	0	0
	處理後² Pact-treatment	0.1	0	0.3	0	0	0	0	0	0	0	0	0
	1	0.1	0	0.7	0	0	0	0	0	0	0	0	0
	2	0	0.1	0.1	0.2	0.5	1.0	0	0.1	0.1	0.3	0.2	3.7
	3	0	0.4	0.2	0.3	0.2	5.0	0	0	0.4	1.2	0	0
	4	0	12.5	0	0.2	0.2	4.6	0	0	0.5	1.9	0	0
	5	0	1.0	1.0	1.0	1.0	6.4	0	0	0.7	24.3	0	0
	6	0	7.0	0.9	2.6	0.1	14.0	0	0	2.1	35.0	0	0
	合計 Total	0.3	21.0	3.3	4.3	2.0	31.0	0	0.1	3.8	62.7	0.2	3.7
	比率 Rate	0.3	2.4	3.3	0.5	2.0	3.6	0	0.1	3.7	7.4	0.2	0.4

袋裝稻穀以 Baythion 燻煙處理後，經貯藏至 6 個月，對袋表面害蟲之防治效果，與未處理對照之差異甚顯著，燻煙者幾無害蟲生存，其防治率高達97.8%；但對袋中稻穀之害蟲治蟲觸殺力較差，防治率僅60.7%，而稻穀受害損失，燻煙者較無處理對照約可減少損失 0.7%。（表 3 ）。在袋外及袋內稻穀中計有害蟲12種，其發生相對密度袋外、袋內均以穀蠹最高，分別爲80.8；89.1—71.2；71.0%，擬穀盜5.6；6.9—16.0；9.3%，角胸粉扁蟲 4.3；1.1—2.0；3.6%，鋸胸粉扁蟲2.8；0.9—3.3；0.5%，麥蛾0.2；0.1—3.7；7.4%，米象 2.6；0.1—2.8；4.7%，長首穀盜0.7；0.3—0.5；0.5%，暹羅穀盜0.6；0.9—0.3；2.4%，小紅鰹節蟲 0.2；0—0.01%，玉米象0；0.1—0；0.1，細擬穀盜0.1；0.1—0；0%，其他包括矮毛鰹節蟲2.0；0.4—0.2；0.4%。（表 4 ）。

袋裝稻穀經貯藏至 4 個月後，以 Phostoxin 燻蒸處理治蟲效果雖十分顯著，但貯藏 4 個月後穀袋表面已有活蟲出現，可能由外界侵入。稻穀受害損失，處理組較對照組減少損失 1.7%。（表 5 ）。其害蟲有11種，發生相對密度亦以穀蠹爲最高，袋外袋內分別爲64.9；88.7—56.0；77.7%，麥蛾16.9；0.5—3.7；0.3%，擬穀盜 6.7；2.6—13.7；6.3%，米象 0；0.2—8.2；5.5%，鋸胸粉扁蟲0.4；1.8—6.6；4.9%，長首穀盜0；1.3—0；0.8%，暹羅穀盜0；0.1—0.9；0%，細擬穀盜0；0.3—0.9；0%，玉米象0；0.1—0；0.1%，其他包括粉斑螟蛾8.9；4.3—1.8；0.8%。（表 6 ）。

袋裝玉米經貯藏 4 個月，以 Baythion 燻煙處理，對袋表面及袋中玉米治蟲效果與處理稻穀者相似。燻煙處理 2 個月後，袋外及袋內害蟲防治率分別達 100與17.2%，而袋中玉米之損失較未處理組減少 2.3%。（表 7 ）。害蟲發生15種，其袋外與袋內相對密度，以玉米象最高分別爲 3.9；22.0—40.3；86.4%，擬穀盜50.4；10.7—17.2；1.1%，角胸粉扁蟲 34.9；33.4—21.9；9.8，穀蠹0.9；

表 5. Phostoxin 燻蒸袋裝稻穀之治蟲效果

Table 5. Effect of fumigation with Phostoxin on the control of insects of bagged rice

用藥量 Dosage T/M³	檢查期間（月） Time of Examination (month)	袋表面 Bag surface 蟲數 insects	袋表面 Bag surface 活蟲率 Percentage of livinginsects	袋表面 Bag surface 防治率% of effectiveness	袋中稻穀 Rice in bag 蟲數 insects	袋中稻穀 Rice in bag 活蟲率 Percentage of livinginsects	袋中稻穀 Rice in bag 防治率% of effectiveness	袋中稻穀 Rice in bag 損失量 Loss	袋中稻穀 Rice in bag 減少損失率 Reduced loss rate
3	處理前 Pre-treatment	—	—	—	—	—	—	—	—
	處理後[1] Post-treatment	40.0	0	100.0	111.3	0	100.0	0.4	0
	1	0	0	100.0	116.3	0	100.0	0.4	1.1
	2	2.0	0	100.0	108.7	0	100.0	0.4	1.4
	3	1.0	0	100.0	104.4	0	100.0	0.4	1.6
	4	2.0	10.0	41.5	83.0	0	100.0	0.4	1.7
0 (CK)	處理前 Pre-treatment	—	—	—	—	—	—	—	—
	處理後[1] Post-treatment	40.0	30.0	0	116.3	31.0	0	0.4	—
	1	10.3	77.7	0	232.6	75.0	0	1.5	—
	2	26.2	5.7	0	465.2	75.0	0	1.8	—
	3	12.6	15.9	0	376.4	65.3	0	2.0	—
	4	23.4	17.1	0	481.3	61.8	0	2.1	—

1.燻蒸處理後經 5 天 (5 days after treatment).

表 6. Phostoxin 燻蒸袋裝稻穀之害蟲發生密度

Table 6. No. of insects found on bagged rice after fumigation with Phostoxin

用藥量 Dosage T/M³	檢查期間(月) Time of Examination (month)	*Sitophilus oryzae*		*Sitophilus zeamais*		*Rhizopertha dominica*		*Tribolium castaneum*		*Gnathocerus maxillosus*		*Latheticus oryzae*	
		Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag
3	處理前 Pre-treatment	—	—	—	—	—	—	—	—	—	—	—	—
	處理後[2] Post-treatment	0	0	0	0	25.0	90.6	3.0	3.0	0	1.7	0	0
	1	0	1.3	0	0.3	0	98.3	0	1.9	0	0	0	0
	2	0	0	0	0	2.0	103.0	0	3.0	0	0	0	1.7
	3	0	0	0	0	0.6	97.7	0	2.0	0	0	0	3.0
	4	0	0	0	0	1.6	74.7	0	3.7	0	0	0	2.3
	合計 Total	0	1.3	0	0.3	29.2	464.3	3.0	13.6	0	1.7	0	7.0
	比率 Rate	0	0.2	0	0.1	64.9	88.7	6.7	2.6	0	0.3	0	1.3
0 (CK)	處理前 Pre-treatment	—	—	—	—	—	—	—	—	—	—	—	—
	處理後[2] Post-treatment	4.0	1.3	0	0.3	23.0	97.6	4.0	1.9	1.0	0	0	0
	1	2.0	13.4	0	0	5.3	171.7	0.2	16.3	0	0	0	0
	2	1.0	26.8	0	0	12.1	337.0	5.1	32.6	0	0	0	6.0
	3	1.2	25.0	0	0	9.4	303.0	1.0	26.4	0	0	0	0
	4	1.0	26.5	0	0	13.2	390.0	5.2	28.0	0	0	0	7.0
	合計 Total	9.2	93.0	0	0.3	63.0	1,299.3	15.5	105.2	1.0	0	0	13.0
	比率 Rate	8.2	5.5	0	0.1	56.0	77.7	13.7	6.3	0.9	0	0	0.8

1.其他包括粉斑螟蛾、椿象、僞蠍、蜘蛛 (Including *Ephestia cautella*, Reduviid bugs, Minute Pirate bug, Pseudoscorphions and Spiders).

2.燻蒸處理後經5天 (5 days after treatment).

續表 6. (Continued table 6.)

用藥量 Dosage T/M³	檢查期間（月）Time of Examination (month)	*Lophocateres pusillus*		*Oryzaephilus surinamensis*		*Cryptolestes ferrugineus*		*Sitotroga cerealella*		Other[1]	
		Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag
3	處理前 Pre-treatment	—	—	—	—	—	—	—	—	—	—
	處理後[2] Post-treatment 1	0	0.3	1.0	0.3	0	3.7	7.0	1.0	4.0	10.7
		0	0	0	0	0	2.6	0	0	0	11.9
	2	0	0	0	0	0	1.0	0	0	0	0
	3	0	0	0	0	0.2	1.0	0.2	0.7	0	0
	4	0	0	0	0	0	1.3	0.4	1.0	0	0
	合計 Total	0	0.3	1.0	0.3	0.2	9.6	7.6	2.7	4.0	22.6
	比率 Pate	0	0.1	2.2	0.1	0.4	1.8	16.9	0.5	8.9	4.3
0 (CK)	處理前 Pre-treatment	—	—	—	—	—	—	—	—	—	—
	處理後[2] Post-treatment 1	1.0	0	4.0	0	1.0	2.6	2.0	0	0	12.6
		0	0	1.2	12.7	1.4	17.7	0.2	0	0	0.8
	2	0	0	3.0	25.4	5.0	35.4	0	2.0	0	0
	3	0	0	0	0	0	20.0	1.0	0	0	2.0
	4	0	0	1.0	18.2	0	7.1	1.0	2.5	2.0	2.0
	合計 Total	1.0	0	9.2	56.3	7.4	82.8	4.2	4.5	2.0	17.4
	比率 Pate	0.9	0	8.2	3.4	6.6	4.9	3.7	0.3	1.8	1.0

7.7—11.9；2.0%，大穀盜0；5.5—5.6；0%，鋸胸粉扁蟲3.1；5.1—0；0.1%，暹羅穀盜0；7.0—0；0.1%，長首穀盜1.5；0—1.9；0%，細擬穀盜2.0；0—0；0%，其他包括米露尾蟲（*Carpophilus obsoletus*），小紅鰹節蟲、煙甲蟲（*Lasioderma serricorne*），背圓粉扁蟲（*Ahasuerus abvena*），麥蛾，粉斑螟蛾，閻魔蟲，郭公蟲，椿象等合計爲3.3；8.6—1.2；0.5%。（表8）。

袋裝高粱以 Baythion 與 Phostoxin+Baythion 二組藥劑分別處理，得知二組藥劑對袋裝表面之治蟲效果甚爲良好，經貯藏至3個月之防治率仍高達100%，但對袋內高粱之治蟲效果，Phostoxin+Baythion 先後施用者顯較僅施用 Baythion 者爲優，貯藏3個月內二者之防治率各爲 100—42.4%與3.5—26.7%。至於高粱之受害損失率，二種處理組均較未處理組減少 0.1—0.2%。（表9）袋裝外及內部害蟲發生有6種，其相對密度則以擬穀盜最高。在 Baythion 單獨處理時，袋裝外與內部之密度分別擬穀盜爲44.4及79.4%，玉米象爲44.4及5.8%，穀蠹11.2及5.8%，角胸粉扁蟲0及7.7%，其他包括長角象鼻蟲（*Araecerus fasciculatus*）、粉斑螟蛾合計爲 0 及 1.3%。Phostoxin 與 Baythion 二種處理者擬穀盜73.1及40.8%，玉米象3.8及39.1%，穀蠹 23.1及7.3%，角胸粉扁蟲 0 及5.6%，其他粉斑螟蛾爲0及7.2%。而未處理對照者擬穀盜 90.9及94.8，穀蠹9.1及0%，其他包括粉斑螟蛾0及5.2%。（表10）。

六種藥劑各以 0.5、0.3及 0.1g（AI）/M^3 三種藥量燻煙處理麻布後，放置於木箱內稻米表面，經至150天，檢查其殘效結果，得知除 Nexion 外，各藥劑高低用藥量燻煙處理間之治蟲殘效有明顯差異，則高藥量以 0.5g（AI）/M^3 毒效消失速度較緩。藥劑之殘效以 Actellic、Baythion、Dursban 及 Elsan 等四種爲佳，經150天後其防治率仍可達25.7—51.6%。而 Phosdrin 及 Nexion 僅能維持120天左右，其防治率爲69.6—44.8%，至150天時防治率僅0—17.6%。（表11）。

討　論

由於現行穀類貯藏已改爲袋裝，爲適應害蟲防治，以 Baythion 燻煙處理操作，不但方法簡便且較安全。在倉庫內以 Baythion 10% 5ml/M^3 用藥量燻煙處理後，雖部份煙霧從屋頂瓦縫、氣窗等處

表 7. Baythion 燻煙處理袋裝玉米之治蟲效果

Table 7. Effect of smoking with baythion on the control of insects of bagged maize

用藥量 Dosage g(AI)/M^3	檢查期間（月） Time of Examination (month)	袋表面 Bag surface 蟲數 insects	活蟲率 Percentage of livinginscts	防治率% of effectiveness	袋中玉米 maize in bag 蟲數 insects	活蟲率 Percentage of livinginscts	防治率% of effectiveness	損失量 Loss	減少損失量 Reduced loss rate
0.5	處理前 Pre-treatment	9.0	14.4	—	13.1	87.0	—	0.2	—
	處理後[1] Post-treatment	32.2	1.2	97.8	12.0	69.2	20.3	0.2	0
	1	1.4	0	100.0	44.2	85.7	6.8	0.9	2.0
	2	3.0	0	100.0	127.0	74.0	17.2	1.7	2.3
0 (CK)	處理前 Pre-treatment	9.0	14.4	—	13.1	87.0	—	0.2	
	處理後[1] Post-treatment	4.0	55.0	0	12.2	86.8	0	0.2	
	1	11.0	20.0	0	315.3	92.0	0	2.9	
	2	12.0	14.2	0	477.5	89.4	0	4.0	

1.燻煙處理後經2天（2 days after treatment).

表 8. Baythion 燻煙處理袋裝玉米之害蟲發生密度

Table 8. No. of insects found on bagged maize after smoking with baythion

用藥量 Dosage g(AI)/M³	檢查期間(月) Time of Examination (month)	*Sitophilus zeamais*		*Rhizopertha dominica*		*Tribolium castaneum*		*Gnathocerus maxillosus*		*Latheticus oryzae*		*Tenebroides mauritanicus*		*Lophocateres pusillus*		*Oryzaephilus surinamensis*		*Cryptolestes ferrugineus*		Other[1]	
		Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag
0.5	處理前 Pre-treatment	0.3	4.1	0.3	0.2	4.2	0.9	0	0	0.7	0	0	0	0	0	0	0	3.1	7.2	0.4	0.5
	處理後[2] Post-treatmetn	0.6	2.7	0.1	2.1	17.8	0.6	0.4	0	0	0	0	0	0	0	0.7	0	12.2	5.6	0.4	1.0
	1	0.4	10.7	0	2.1	0.4	4.3	0.1	0	0	0	0	0.3	0	1.3	0.2	0.8	0.1	22.8	0.1	1.9
	2	0.5	25.6	0	10.7	0.6	15.3	0.4	0	0	0	0	10.4	0	12.5	0.5	9.3	0.5	30.0	0	13.2
	合計 Total	1.8	43.1	0.4	15.1	23.0	21.1	0.9	0	0.7	0	0	10.7	0	13.8	1.4	10.1	15.9	65.6	0.9	15.8
	比率 Rate	3.9	22.0	0.9	7.7	50.4	10.7	2.0	0	1.5	0	0	5.5	0	7.0	3.1	5.1	34.9	33.4	3.4	8.6
0 (KC)	處理前 Pre-treatment	0.3	4.1	0.3	0.2	4.2	0.9	0	0	0.7	0	0	0	0	0	0	0	3.1	7.2	0.4	0.7
	處理後[2] Post-treatment	1.2	2.7	1.0	2.2	0	0.6	0	0	0	0	0	0	0	0	0	0	1.8	5.7	0	1.0
	1	6.0	281.3	1.0	5.7	1.0	0.6	0	0	0	0	1.0	0	0	0.3	0	0.9	2.0	25.9	0	0.6
	2	7.0	419.3	2.0	8.4	1.0	7.3	0	0	0	0	1.0	0	0	0	0	0	1.0	42.5	0	0
	合計 Total	14.5	707.4	4.3	16.5	6.2	9.4	0	0	0.7	0	2.0	0	0	0.3	0	0.9	7.9	81.3	0.4	2.3
	比率 Rate	40.3	86.4	11.9	2.0	17.2	1.1	0	0	1.9	0	5.6	0	0	0.1	0	0.1	21.9	9.8	1.2	0.5

1. 其他包括米露尾蟲、煙甲蟲、背圓粉扁蟲、小紅鰹節蟲、麥蛾、粉斑螟蛾、閻魔蟲、郭公蟲、椿象。(Including *Carpophilus obsoletus, Lasioderma serricorne, Ahasuerus advena, Trogoderma granarium, Sitotroga cerealella, Ephestia cautella*, Hister beetles, Clerid beetle, Reduviid bugs and Minute pirate bug).
2. 燻煙處理後經 2 天 (2days after treatment).

表 9. 藥劑燻煙及燻蒸處理袋裝高粱之治蟲效果

Table 9. Effect of smoking and fumigation on the control of insects of bagged sorghum

藥劑 Chemicals	用藥量 Dosage (M³)	檢查期間 (月) Time of Examination (month)	袋表面 Bag surface 蟲數 insects	袋表面 Bag surface 活蟲率 Percentage of livinginsncts	袋表面 Bag surface 防治率% of effectiveness	袋中高粱 Sorghum in bag 蟲數 insects	袋中高粱 Sorghum in bag 活蟲率 Percentage of ivinginscts	袋中高粱 Sorghum in bag 防治率 % of effectiveness	袋中高粱 Sorghum in bag 損失量 Loss	袋中高粱 Sorghum in bag 減少損失率 Reduced loss rate
Baythion 10%	5ml	處理前 Pre-treatment	0.6	33.2	—	5.0	80.0	—	—	—
		處理後[1] Post-treatment	0.2	0	100.0	10.0	90.0	0	0.2	0
		1	0.2	0	100.0	2.0	66.0	3.5	0.2	0.1
		2	0	0	100.0	2.0	75.0	25.0	0.3	0.2
		3	0.8	0	100.0	3.3	54.5	26.7	0.6	0.2
Phostoxin 55% + Baythion 10%	3T 5ml	處理前 Pre-treatment	0.8	37.5	—	3.3	69.7	—	—	—
		處理後[2] Post-treatment	0.2	0	100.0	3.0	0	100.0	0.2	0
		1	0.8	0	100.0	2.0	0	100.0	0.2	0.1
		2	0.2	0	100.0	2.3	26.1	73.9	0.3	0.2
		3	0.6	0	100.0	7.3	41.1	42.4	0.6	0.2
CK	0	處理前 Pre-treatment	0.4	25.0	—	1.9	68.4	—	—	
		處理後[1] Post-treatment	0.4	25.0	0	1.9	68.4	0	0.2	
		1	0.4	50.0	0	1.9	68.4	0	0.3	
		2	1.6	62.5	0	4.7	100.0	0	0.5	
		3	1.6	62.5	0	7.0	71.4	0	0.8	

1.燻煙處理後經 2 天 (2 days after treatment).

2.燻蒸處理後經 7 天 (7 days after treatment).

外洩，然經 2 天後，空倉中或墊倉穀殼中之治蟲效果達 81—100%，倉庫中袋裝穀類經燻煙處理，對穀袋表面治蟲具有 100%效果，但對袋中穀類之害蟲防治僅爲 61%。筆者建議如袋中穀類蟲害發生時，先以 Phostoxin 燻蒸處理後，再用 Baythion 燻煙處理，則治蟲效果更爲顯著，且均能貯藏 6 個月以上。

以六種藥劑燻煙處理麻布，測定其對害蟲之殘毒效果，以Actellic, Baythion, Dursban, Elsan 之殘效較能維持長久，但藥劑中除 Baythion 可列入積穀害蟲防治推廣外，餘者倉庫實地進一步治蟲效果試驗，與對高等動物小白鼠毒害試驗後，才能決定推廣採用。

採用燻煙法，操作較安全，藥煙可從倉門口噴入，其噴煙機之噴煙口前端應距離袋裝穀類 60cm 以上，並在袋表面舖放鐵板或木板以防火災。

盛裝穀類之麻袋，如未預先經適當治蟲處理，即用以盛裝穀類貯藏，麻袋常殘存害蟲，故能加速害蟲發生繁殖，且不甚衛生。特建議有關單位對盛裝穀類之空袋，應先集中燻蒸或燻煙處理，減少蟲源。

燻煙與燻蒸處理之經濟效益評估，在相同體積之燻煙成本僅佔燻蒸費用⅕，且處理簡便而安全。

表 10. 藥劑燻煙及燻蒸處理袋裝高粱之害蟲發生密度

Table 10. No. of insects found on hagged sorghum after smoking or fumigation treatments

藥劑 Chemicals	用藥量 Dosage (M^3)	檢查期間 (月) Time of Examination (month)	*Sitophilus zeamais*		*Rhizopertha dominica*		*Tribo lium castaneum*		*Cryptolestes ferrugineus*		Other [1]	
			Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag	Bag surface	In bag
Baythion 10%	5ml	處理前 Pre-treatment	0.2	0.3	0.2	0.3	0.2	3.7	0	0.7	0	0
		處理後[2] Post-treatment	0	0	0	0	0.2	10.0	0	0	0	0
		1	0	0	0	0	0.2	1.0	0	1.0	0	0
		2	0	0	0	0	0	2.0	0	0	0	0
		3	0.6	1.0	0	1.0	0.2	1.0	0	0	0	0.3
		合計 Total	0.8	1.3	0.2	1.3	0.8	17.7	0	1.7	0	0.3
		比率 Rate	44.4	5.8	11.2	5.8	44.4	79.4	0	7.7	0	1.3
Phostoxin 55% Baythion 10%	3T+5ml	處理前 Pre-treatmen	0	0	0.4	0.3	0.4	3.0	0	0	0	0
		處理後[3] Post-treatment	0.1	0	0	1.0	0.1	2.0	0	0	0	0
		1	0	0	0	0	0.8	0.7	0	1.0	0	0
		2	0	0.3	0.2	0	0	1.0	0	0	0	0
		3	0	6.7	0	0	0.6	0.6	0	0	0	0
		合計 Total	0.1	7.0	0.6	1.3	1.9	7.3	0	1.0	0	0
		比率 Rate	3.8	39.1	23.1	7.3	73.1	40.8	0	5.6	0	0
CK	0	處理前 Pre-treatment	0	0	0	0	0.4	1.6	0	0	0	0
		處理後[2] Post-treatment	0	0	0	0	0.4	1.6	0	0	0	0
		1	0	0	0	0	0.4	1.6	0	0	0	0
		2	0	0	0.2	0	1.4	4.7	0	0	0	0
		3	0	0	0.2	0	1.4	7.0	0	0	0	0
		合計 Total	0	0	0.4	0	4.0	16.5	0	0	0	0
		比率 Rate	0	0	9.1	0	90.9	94.8	0	0	0	0

1.其他包括長角象鼻蟲、粉斑螟蛾 (Including *Araecerus fasciculatus* and *Ephestia cautella*).
2.燻煙處理後經2天 (2 days after treatment).
3.燻蒸處理後經7天 (7 days after treatment).

表 11. 六種藥劑燻煙處理蔴布之治蟲殘效

Table 11. Mortality of storage insects after fiber sack clothes were treated by smoking method

藥劑 Chemicals	用藥量 Dosage g(AI)/M³	30 day 蟲數 Total of insects	30 day 防治率% of effectiveness	90 day 蟲數 Total of insects	90 day 防治率% of effectiveness	150 day 蟲數 Total of insects	150 day 防治率% of effectiveness
Actellic 90%	0.5	51	67.2	294	78.4	522	51.6
	0.3	117	27.5	370	79.4	416	44.5
	0.1	79	5.5	441	34.2	587	11.3
Baythion 84.5%	0.5	41	56.5	413	80.8	391	42.5
	0.3	38	61.9	489	38.7	554	1.0
	0.1	87	29.5	457	38.1	348	2.8
Dursban 99%	0.5	99	51.6	405	59.7	608	25.7
	0.3	25	42.0	388	60.9	551	0.8
	0.1	86	29.9	397	60.3	612	0
Elsan 92%	0.5	50	68.8	399	77.9	410	41.3
	0.3	108	27.8	410	84.1	390	13.8
	0.1	103	9.0	489	38.4	399	0
Phosdrin 100%	0.5	63	62.9	850	84.7	712	17.6
	0.3	37	42.7	452	76.0	559	0
	0.1	43	48.2	606	33.3	538	0
Nexion 90%	0.5	40	24.7	210	61.5	420	0
	0.3	19	23.7	360	62.3	413	0
	0.1	28	28.4	245	68.8	327	0
CK	0	58	0	322	0	530	0

表 12. 燻煙及燻蒸防治倉儲害蟲之效益評估

Table 12. Cost of storage insect control by smoking and fumigation method

	燻煙 Smoking		燻蒸 Fumigation	
體積 Space		1,089M³		1,089M³
使用藥劑及用量 Chemical and Dosage	Baythion 10% Oil	5.4公升	Phostoxin tablets	2,178片
藥劑費用 Cost of chemical		2,592元		17,424元
噴煙器成本折舊 depreciation of machine		250元		
汽油 Fuel		24元		
密閉材料 materials for sealing				174元
工資 Wages		37.5元		150元
合計 Total		2,903.5元		17,748元

可供今後倉儲害蟲防治之依據（表12）。

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Studies on control of insect pests of stored grain with insecticide smokes[1]

Tsung Lin[2]

Summary

Experiments were conducted at 3 empty warehouses with husks, 3 warehouses with bagged rice, 2 warehouses with bagged corn and 2 with bagged sorghum. Treating the warehouses with Baythion smoke at the rate of 0.5g (AI)m^3 for 2 days for pest control was economic and effective. The treatment has killed 20 spp. of insects in empty warehouses, 11 spp. of insects in hus/ks, and 15 spp. of insects on bag surfaces. Fumigate with Phostoxin at 3 tab/M^3 for 5 days was effective for emergency insect control. This fumigation followed with the treatment of Baythion smoke gave a more satisfied insect control effect.

The residue effect of insect control on the surface of fiber bags lasted for 5 months, in the treatments of Actellic, Baythion, Dursban and Elsan, gave more ideal residue effect for insect control.

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Insecticide Resistance Study in *Plutella xylostella* (L.)

VIII. The Specificity of Oxidative Detoxication Mechanism in Larval Stage[1]

Edward Y. Cheng, C. H. Kao, D. F. Lin and T. C. Tsai[2]

Abstract: In this study, we have observed that the resistance of DBM to organophosphorus insecticides are not associated with MFOs, and the natural declining rate of organophosphorus-resistance is closely correlated with the resistance level of different compounds in the field. Mevinphos, phenthoate, and methidathion are three organophosphorus insecticides with the fastest resistance declining rate, and also meet minimum resistance problem in the field On the other hand,methamidophos, mephosfolan, and diethquinalphion have the slowest rate and also met with enormous resistance in the field. Synthetic pyrethroids and carbamates are chiefly detoxicated by MFOs in DBM. By using separate DBM strains and with the help of piperionyl butoxide and other synergists, we have concluded that DBM can develop three separate MFOs for (1) synthetic pyrethroids, (2) carbofuran, and (3) carbaryl, propoxur, and methomyl. It seems that the cross resistance is not existed among three MFOs sub-systems. The evidences are present in Tables and discussed in the text.

Introduction

There are many insecticides has been used for controlling the diamondback moth, *Plutella xylostella* (L.), in Taiwan over the past 15 years. Recently we have found that some of these insecticides still retain good control efficacy despite the insects can generate high resistance to insecticides [18] rapidly. Mevinphos, phenthoate, and methidathion are belonged to this catagory of durable insecticides and they are all organophosphorus (OP) compounds. So far there is no explanation for it. The DBM usuallly generate higher resistance toward carbamates and synthetic pyrethroids (SP) than that for the OP-insecticides [7,11]. The mixed function oxidases (MFOs) are closely

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associated with the SP-resistance in DBM[19], but their relationship with other insecticide resistances has not been clarified yet. The MFOs are the main detoxication mechanism for pyrethrin[12,23] and carbamates[6,21], and they also involve in the activation/inactivation of OP insecticides *in vivo*[16,17].

In the western coast of Taiwan, the DBMs are highly resistant to both synthetic pyrethroids and carbamates except carbofuran[7,10,18]. However, low degree of carbofuran resistance is commonly existed and no correlation to other insecticide resistance has been found[18]. We had reported that the DBM from I-lan county was extremely sensitive to both carbofuran and synthetic pyrethroids but not to other carbamates[11]. Are the MFOs responsible for this ? Usually, the MFOs are treated as one entity with many common features; Agosin[2] had pointed out that: "the possibility of several MFOs in insects, instead of a single non-specific one"; Yu and Terriere[27,28] had confirmed the existence of multiple-forms cytochrome P-450, a constitute of MFOs, in several dipterous species. The MFO-diversity may exist in the DBM as well as in the dipterous species. Besides, the substrate-specificity of different MFOs in Ndealkylation, S-dealkylation, O-dealkylation, and aromatic ring-hydroxylation etc., also make the detailed analysis of MFOs action difficult. Whether the MFOs can cause cross resistance among different insecticides is the major interest in this investigation; although the minor cross effect seems unavoidable, only the serious cross resistance is the target for studying.

In the following study, we will compare: (1) the declining rate of resistance after the DBMs were relieved from insecticide-selection pressure, (2) the MFOs activity in relation to different insecticide resistances, with special emphasis on the substrate-specificity of MFOs toward different insecticides.

Materials and methods

Insecticides: compounds used in both the resistance decline study and the MFOs activity in relation to different insecticide resistances study were commercial grade mevinphos, profenofos, prothiofos, methidathion, mephosfolan, phenthoate, diethquinalphion, methamidophos, decamethrin, permethrin, fenvalerate, carbofuran, carbaryl, methomyl, and propoxur. Insecticides were diluted in water to proper concentrations for assay through the Burkard Potter spray tower. In the MFOs substrate-specificity study, purified carbaryl, methomyl, propoxur, and carbofuran were dissolved in acetone and applied topically on the insects by the microapplicator.

Synergists: piperionyl butoxide (pb) was obtained from Tokyo Kasei; MGK 264 was a gift from Cheng-Hong Chemical Co., Ltd.; and 4-chloro-1-naphthyl 2-propynyl ether (pe) was obtained from Union Carbide, Taiwan Ltd.

Testing procedures and insects:

1. The resistance decline study--the resistant DBM was collected from an intensively cultivated vegetable district near Taipei. The starting generation for testing was F_2 because the F_1 generation was solely used for propagating sufficient DBM. The susceptibi-

lities of DBM to 12 insecticides were tested on F_2, F_5, F_8 and F_{11}, or at 3-generations interval. Usually, 7 dosages from LC_{10} to LC_{95} were made in distilled water for testing. Each dosage was tested on 40-60 third instar DBM larvae in three replicas. The testing procedure is the same spraying operation adapted in this laboratory[11]. The post-treatment holding temperature and relative humidity were controlled at 25±1°C and 85±10% respectively. The mortality of treated insects was counted at 24 hours after the spray, and all results were analyzed in probits[15].

2. The study of MFOs activity in relation to different insecticide resistances--the susceptible I-lan strain and the F_5 generation of Taipei resistant strain were used to test the role of oxidative detoxication toward different insecticides. Two commercial synergists, pb and MGK 264 were added into insecticides at 5 to 1 ratio then followed the spray-testing procedure as described in (1).

3. The MFO specificity test--in order to resolve the specificity of MFOs toward different carbamates, a highly resistant DBM strain from Taichung was used. Instead of the spraying method, the topical application method was adapted and the insec ticide/acetone solution with or without synergist were used in the treatment. The less effective MGK 264 was substituted by a stronger synergist, pe[3,14,25]. All changes are aimed at providing more direct and precise measurement in MFO's substrate-specificity. The third instar larvae were immobilized in a petri dish placed on ice. Each larva receive 0.5μl acetone solution of designated insecticide/synergist combination through the syringe from microapplicator. Seven dosages within the LD_{10} to LD_{95} of each insecticide or insecticide/synergist treatment were tested on 60 larvae in three replicas. All post-treatment handling were the same as that of (1).

Table 1. The susceptibility changes of resistant DBM to twelve commonly used insecticides after the insecticide pressure was relieved.

Insecticides	LC_{50} in ppm, (slope)				The lowest LC_{50} ever recorded in Taiwan (ppm)
	F_2	F_5	F_8	F_{11}	
Organophosphorus					
Mevinphos	537.1 (1.57)	232.9 (1.06)	161.7 (1.05)	220.1 (1.37)	73*
Profenofos	928.8 (1.28)	662.2 (1.11)	558.5 (0.99)	410.4 (1.05)	100*
Prothiofos	2,683.6 (1.44)	2,165.3 (0.93)	1,112.8 (1.16)	1,219.0 (1.45)	310*
Methidathion	776.1 (1.48)	464.9 (2.47)	322.4 (1.13)	490.3 (1.73)	270*
Mephosfolan	1,487.0 (0.97)	2,456.0 (0.82)	743.5 (0.82)	1,796.1 (0.91)	320**
Phenthoate	1,161.7 (1.37)	677.3 (1.19)	444.8 (0.75)	77.1 (1.34)	262***
Diethquinalphion	1,954.4 (1.24)	1,755.2 (0.92)	1,192.7 (0.95)	3,059.4 (0.86)	230*
Methamidophos	3,269.2 (1.44)	3,983.7 (0.91)	1,778.9 (1.23)	3,579.0 (1.34)	560*
Synthetic pyrethroids					
Decamethrin	656.2 (1.03)	214.7 (0.46)	65.2 (0.47)	92.9 (0.79)	4*
Fenvalerate	1,862.7 (1.76)	757.0 (0.61)	179.6 (0.77)	221.9 (0.93)	9*
Permethrin	1,148.8 (1.18)	353.2 (0.85)	64.0 (0.99)	43.61 (1.55)	14*
Carbamate					
Carbofuran	763.5 (1.25)	570.0 (0.67)	213.7 (0.38)	241.7 (0.74)	75***

*Reference 11.

**Recorded on DBMs of Su-ao of I-lan county in 1982. Unpublished information.

***Recorded on DBMs of Tou-cheng of I-lan county in 1982. Unpublished information.

Results

1. The resistance decline study: once the insecticide selection pressure was removed, the resistant DBM gradually relieved their resistance toward all three major groups of insecticides (Table 1). The lowest insecticide LC_{50}s ever recorded for DBM in Taiwan were also given. The data in Table 1 were then converted to resistance ratios (R. R.) for comparison, and their resistance declining rate were also calculated in Table 2. Compared to other insecticides, the synthetic pyrethroids had met with the strongest resistance as the R. R. ranged from 82.06 to 206.96; the ratios were 10.18 for carbofuran and 2.87-9.29 for eight OP compounds. The SP-resistance declined very rapidly, and the declining rates were extremely similar among three tested compounds; only one-tenth of original resistance remained after 6 insecticide-free generations for all three synthetic pyrethroids tested. Carbofuran resistance declined rather slowly in the beginning and then in a much faster pace which was next to that of SP-resistance, but still faster than the OP-resistance.

Table 2. The decrease of resistance to twelve commonly used insecticides of a resistant DBM strain after relieving from the insecticide pressure.

Insecticides	Resistance Ratio*				% Decreases			
	F_2	F_5	F_8	F_{11}	F_2	F_5	F_8	F_{11}
Organophosphorus								
Mevinphos	7.35	3.19	2.22	3.01	0.0	56.6	69.9	59.0
Profenofos	9.29	6.62	5.59	4.10	0.0	28.7	39.9	55.8
Prothiofos	8.66	6.98	3.59	3.93	0.0	19.3	58.5	54.6
Methidathion	2.87	1.72	1.19	1.82	0.0	40.1	58.5	36.6
Mephosfolan	4.65	7.68	2.32	5.61	0.0	0.0	50.0	0.0
Phenthoate	4.43	2.59	1.70	0.29	0.0	41.7	61.7	93.4
Diethquinalphion	8.50	7.63	5.19	13.30	0.0	10.2	39.0	0.0
Methamidophos	5.84	7.11	3.18	6.39	0.0	0.0	45.6	0.0
Synthetic pyrethroids								
Decamethrin	164.05	53.68	16.30	23.22	0.0	67.3	90.1	85.8
Fenvalerate	206.96	84.11	19.96	24.66	0.0	59.3	90.4	88.1
Permethrin	82.06	25.23	4.57	3.12	0.0	69.3	94.4	96.2
Carbamate								
Carbofuran	10.18	7.60	2.84	3.22	0.0	25.3	72.0	68.3

*Calculated from Table 1.

After 9 insecticide-free generations, the resistances of F_{11} to eight OP compounds had declined 0~93. 4% in the order of: phenthoate>mevinphos>profenofos>prothio-

fos>methidathion>mephosfolan>methamidophos>diethquinalphion. In F_5, the differences between compounds were already obvious. The reduction of resistance for mevinphos, phenthoate, and methidathion were 40-60%, while the resistance for mephosfolan, methamidophos, and diethquinalphion showed no reduction at all.

2. The study of MFOs activity in relation to different insecticide resistances: the responses of both susceptible and resistant DBM to three major catagories of insecticides and their mixtures with pb or MGK 264 were compared in Table 3, 4, and 5. No ill effect was noticed in insects treated with the synergists only at the test concentration. Both synergists exerted none or only minor synergistic effects on the OP insecticides in DBM (Table 3). For pb, the synergistic ratios varied from 0.76-2.74 and 1.04-2.25 for the susceptible and resistant DBM respectively. Meanwhile, MGK 264 did not induce different results from that of pb.

Table 3. The effects of piperionyl butoxide and MGK 264 on the DBM resistance to organophosphorus insecticides. (LC_{50} in ppm)

Insecticides	Original	+PB		+MGK 264	
	LC_{50} (slope)	LC_{50} (slope)	S. R.*	LC_{50} (slope)	S. R.*
Susceptible strain					
Mevinphos	90.8 (1.08)	37.7 (1.05)	2.41	106.3 (1.06)	0.85
Profenofos	367.0 (0.94)	134.1 (1.38)	2.74	237.6 (0.98)	1.54
Prothiofos	831.0 (0.79)	710.2 (0.70)	1.17	410.1 (0.55)	2.03
Methidathion	451.9 (0.87)	282.6 (0.87)	1.59	171.7 (0.94)	2.63
Phenthoate	283.9 (0.76)	371.4 (0.65)	0.76	347.9 (1.31)	0.82
Resistant strain					
Mevinphos	232.9 (1.06)	122.6 (1.13)	1.89	164.1 (0.97)	1.42
Profenofos	662.2 (1.11)	294.5 (1.82)	2.25	298.2 (0.62)	2.20
Prothiofos	2,165.3 (0.93)	1,526.7 (1.74)	1.42	901.9 (0.90)	2.40
Methidathion	464.8 (2.47)	447.0 (1.05)	1.04	445.2 (1.13)	1.04
Phenthoate	677.3 (1.19)	320.6 (1.01)	2.11	422.5 (0.86)	1.60

* S. R. =the synergistic ratio

On the contrary, the synergists resulted significant synergistic effects in the synthetic pyrethroids (Table 4). With the help of pb, the resistant DBM restored their SP-sensitivity as that of the susceptible DBM. MGK 264 is less effective than pb. In contrast to the lowest LC_{50} ever recorded in Taiwan, there is a minor portion of SP-resistance which was not overcome by the action of MFO inhibitor-type synergists.

Table 4. The effects of piperionyl butoxide and MGK 264 on the DBM resistance to synthetic pyrethroids. (LC_{50} in ppm)

Insecticides	Original	+5 PB		+5 MGK 264	
	LC_{50} (slope)	LC_{50} (slope)	S. R.	LC_{50} (slope)	S. R.
Susceptible strain					
Decamethrin	26.2 (0.62)	15.0 (1.02)	1.75	14.2 (0.57)	1.85
Fenvalerate	48.4 (0.68)	40.6 (1.11)	1.19	40.4 (1.08)	1.20
Permethrin	98.0 (1.18)	44.1 (1.18)	2.22	45.8 (0.50)	1.14
Resistant strain					
Decamethrin	214.7 (0.46)	35.6 (0.99)	6.00	64.2 (0.61)	3.34
Fenvalerate	756.9 (0.61)	45.9 (0.96)	16.50	58.2 (0.77)	12.99
Permethrin	353.2 (0.85)	44.8 (1.43)	7.88	168.9 (1.24)	2.09

The test results of carbamates (Table 5) demonstrated that the MFOs of DBM have different substrate-preference for carbaryl and carbofuran. It was noticed that the original LC_{50} difference between carbaryl and carbofuran in the susceptible strain were enormous, i.e., 16,426 vs. 150ppm. After the pb was incorperated, the LC_{50} difference was narrowed to 350.7 vs. 106.7ppm, or only 3 fold. The synergistic ratios were 46.83 vs. 1.40, which indicated that the carbaryl can be effectively synergized by pb but not for carbofuran. It is not probable that pb can discriminate different carbamates, but rather due to the MFOs with greater substrate-affinity for carbaryl than carbofuran.

Table 5. The effects of piperionyl butoxide and MGK 264 on the DBM resistance to carbamates. (LC_{50} in ppm)

Insecticides	Original	+5 PB		+5 MGK264	
	LC_{50} (slope)	LC_{50} (slope)	S. R.	LC_{50} (slope)	S. R.
Susceptible strain					
Carbaryl	16,426.4 (1.05)	350.7 (1.15)	46.83	—	—
Carbofuran	150.3 (0.57)	106.7 (1.20)	1.40	63.8 (0.95)	2.40
Resistant strain					
Carbaryl	21,818.0 (0.82)	544.2 (1.24)	40.09	1,067.2 (0.98)	20.4
Carbofuran	570.0 (0.67)	105.4 (0.97)	5.40	149.3 (1.04)	3.8

The carbofuran-preferred MFOs were better developed in the resistant DBM, and the LC_{50} was 570.0ppm or 3.8 fold of that for the susceptible DBM. The MFOs activity

probably was induced, and subjected to the inhibitory action of pb. The pb had successfully restored the carbofuran-sensitivity in both resistant and susceptible DBMs as their LC_{50}s were 105.4 and 106.7ppm, respectively.

3. The MFO specificity study: in combination with pb or pe, four carbamates were tested on both the susceptible and the highly resistant Taichung strain (Table 6).

Table 6. The selectivity of the DBM's oxidative detoxication towards different carbamates. (LD_{50} in ng per insect)

Insecticides	Original	+5 PB		+2 PE	
	LD_{50} (slope)	LD_{50} (slope)	S. R.	LD_{50} (slope)	S. R.
Susceptible strain					
Carbaryl	4,656.8 (0.54)	190.1 (1.04)	24.5	166.1 (0.59)	28.0
Methomyl	1,900.5 (0.82)	172.6 (0.98)	11.0	102.5 (1.36)	18.6
Propoxur	2,160.8 (0.61)	205.3 (0.82)	10.5	142.9 (0.91)	15.1
Carbofuran	75.2 (0.44)	26.7 (0.84)	2.8	17.1 (1.02)	4.4
Highly resistant strain					
Carbaryl	— *	342.2 (0.89)	—**	465.5 (1.19)	—**
Methomyl	19,674.4 (0.43)	381.4 (1.41)	51.6	262.4 (1.81)	75.0
Propoxur	— *	430.2 (1.14)	—**	285.1 (1.78)	—**
Carbofuran	263.7 (0.58)	111.2 (0.51)	2.4	66.1 (0.97)	4.0

*concentration is too high to be determined by topical application method.

**can not be calculated.

In the susceptible strain, the MFOs had the substrate preferences in the order of carbaryl>propoxur>methomyl>>carbofuran. The affinities for the first three carbamates were very similar as the differences among them were no more than 3 fold. The affinity for carbofuran is 25.3, 28.7, and 61.9 fold lower than methomyl, propoxur, and carbaryl, respectively. By adding the synergists, all three ineffective carbamates had recovered their insecticidal potencies against the DBM as the LD_{50}s shown in Table 6 were effectively lowered 10-24 fold. Again, carbofuran was not synergized so much as other carbamates; this discrepancy indicated that limited MFOs activity toward carbofuran is existing in the DBM. Similar synergistic ratios were recorded in both the susceptible and the resistant DBM, except the synergistic ratios increased 4-5 fold for methomyl in the resistant DBM.

Due to the limitation of testing method and the high resistance, the toxicity of carbaryl and propoxur to the highly resistant Taichung DBM could not be measured; the LD_{50} of methomyl was measured at 19,674.4ng/insect, which was 10 fold higher than that of the susceptible DBM. Once the synergist was added, even the highly resistant DBM

became susceptible to all carbamates as their LD_{50}s were lowered to 342.2, 381.4, and 430.2ng/insect for carbaryl, methomyl, and propoxur, respectively. The result of pe test is very similar to that of pb except the synergistic effect of pe is stronger.

Discussion

Important information concerning the DBM resistance to insecticides was gathered in this investigation and would be helpful in clarifying how and why the DBM is responded to different insecticides.

The resistance declining rate in the short span of generations (F_5)is important because the DBMs in vegetable field hardly have a chance to escape from the insecticide contact in a prolonged period. Hence in practical sense, the results of F_5 in Table 2 are more useful in predicting the resistance developing trend for an insecticide than that of F_8 or F_{11}.

In the OP insecticides, mevinphos, phenthoate, and methidathion are the compounds with the fastest declining rates in resistance; coincidentally,these three compounds had met the slightest resistance in the field. On the other hand, methamidophos, mephosfolan, and diethquinalphion had the slowest rates and also met with enormous resistance [18]. Due to the resistance declining order matched the status of resistance in the field, we suspected that the natural declining rate of resistance for OP insecticides is one of the main reasons why some OP insecticides still retain their DBM control efficacies despite the long period of field usage.

Our test results had showed that the OP-resistance was not reduced by pb, in other word, was not related to the MFOs action. The induction and reduction of MFOs activity usually are rapid, and the independence of OP-resistance from MFOs may be the explanation why OP-resistance can not reach the high level for both carbamates and synthetic pyrethroids. For example, the OP-resistance was ranged 2.87-9.26 fold(Table2), while 40-200 fold resistances were easily recorded for carbaryl and synthetic pyrethroids. However, the OP-resistance of DBM may associate with other factors such as esterases, hydrolases, glutathione-S-transferases or acetylcholinesterase-insensitivity [8,9,16,22] etc.

Liu et al. had reported that pb could successfully synergize fenvalerate, decamethrin, and permethrin; their synergistic ratios were ranged 1.8-4.3 for the susceptible FS strain and 5.7-15.4 for the resistant BC strain [19]. In contrast, we have found the synergistic ratios were 1.2-2.2 for the susceptible I-lan strain and 6.0-16·5 for the F_5 generation of resistant Taipei strain. In both studies, fenvalerate is the one with both the highest resistance and synergistic ratio as compared to other synthetic pyrethroids. Whether the substrate-preference is existed in the MFOs for different synthetic pyrethroids is an interesting matter for further investigation. The low synergistic ratios observed in I-lan strain have confirmed a long suspected fact that the DBM in I-lan area has not developed the MFOs for detoxicating synthetic pyrethroids yet.

Although the SP-resistance declined in a very fast pace, the remained resistance is still too high for the practical use of synthetic pyrethroids.

We also observed a portion of SP-resistance that was not eliminated by pb and hence was not related to the action of MFOs. The magnitude of this pb-insensitive resistance is

ranged 3-9 in resistance ratios for different compounds and its origin is not clear. Liu et al. recorded a 2 fold synergism by esterase inhibitors in synthetic pyrethroids while with the highest synergistic effect for permethrin. The finding is more obvious in the FS strain than in the resistant BC strain indicating that the esterase for detoxication may be induced by either synthetic pyrethroids [19] or other factors. Riskallah had reported the increase in esterase activity was closely associated with the development of SP-resistance in *Spodoptera littoralis* [24]. Is the pb insensitive SP-resistance due to the esterase activity? Can this SP-resistance exert cross effect in detoxicating OP insecticides? However, minor cross resistance had been observed in our previous study [10].

Another important part of this study is that DBM's MFOs do not detoxicate carbofuran as effectively as other carbamates, unless the carbofuran-preferred MFO was first induced. We had found that carbofuran acted differently from other carbamates in their corresponding toxicities on DBMs, and the carbofuran resistance also acted independently from other insecticides [11]. Current investigation result has re-confirmed those findings. Most carbamates are not effective DBM control agents even for the susceptible I-lan strain [11]. Coincide with our finding, Liu et al. had tested 15 insecticides on their highly susceptible FS strain, and the three least effective insecticides on the list were carbaryl, propoxur, and methomyl [20]. Brattsten and Metcalf had reported that the MFOs activity is not the same in natural insect populaion [4,5]; the houseflies, *Musca domestica*, served as a good example that even in the susceptible strain, the naturally occurring MFOs is enough to immune the insects from the lethal action of carbaryl [13,26]. It is doubtful that how important the induced MFO is responsible for the carbaryl-resistance (or carbaryl-tolerance) in DBM, compared to the naturally occurring MFOs which also exert its cross resistance to propoxur and methomyl. The MFOs is definitely the most important single detoxication mechanism in DBM for both carbamates and synthetic pyrethroids, and all above mentioned MFOs activities ares ubjected to the inhibitory action of pb, MGK 264, and pe.

Base upon the findings of (1) the I-lan strain is susceptible to both synthetic pyrethroids and carbofuran but not three other carbamates; (2) the Taipei strain is resistant to carbaryl and synthetic pyrethroids but only mild resistant to carbofuran; (3) the SP-resistance and carbofuran-resistance have different declining rates; (4) no corelation can be found between SP-resistance and carbofuran-resistance in field survey [10]; (5) the Taichung strain is extremely insensitive to most carbamates but only mild resistant to carbofuran; and (6) in the carbofuran selection, the susceptible I-lan strain rapidly developed 36 fold resistance in 8 generations and with no sign of cross resistance to other insecticides [11], we can tentatively concluded that there are three catagories of MFOs in DBM for detoxicating the insecticides: one for the synthetic pyrethroids, one for carbofuran, and another for other carbamates. It is unlikely that the cross resistance is existed among these three catagories of MFOs in DBMs.

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小菜蛾抗藥性之研究

Ⅷ 幼蟲體內氧化解毒酵素之專屬性[1]

鄭 允 高靜華 林端方 蔡湯瓊[2]

摘要

本研究之目的在於測定小菜蛾幼蟲體內氧化解毒酵素對各類殺蟲劑之專屬性，以探討是否與抗藥性有關。以不同地區採得之感性及抗性小菜蛾爲材料，除比較不同殺蟲劑之感度，折算成抗性比率外；並觀察抗性小菜蛾不再接觸農藥後，抗藥性下降的情形。另一方面，利用氧化解毒酵素之抑制劑(就毒效而言爲協力劑，如 piperionyl butoxide)，測定對各種殺蟲劑的協力程度，以決定氧化酵素對該殺蟲劑抗性所扮演之角色及其比重。結果發現有機磷類殺蟲劑受氧化解毒酵素影響甚小，與其抗藥性幾乎無關；但在試驗中發現小菜蛾幼蟲對美文松、賽達松及滅大松之抗性消退甚快，而對拜裕松、達馬松及美福松之抗性消退極慢，此一現象正好與該等藥劑在田間小菜蛾之抗性高低相吻合。影響抗藥性消退速率的原因，目前尙不淸楚，小菜蛾對有機磷之抗性程度一向不及對氨基甲酸鹽或合成除蟲菊精劑，可能是與氧化解毒酵素無關之故。就合成除蟲菊精類殺蟲劑而言，3種供試藥劑幾乎有相同之抗性消退速率，經過6代以後，抗性消退至原來抗性之1/10；雖然其抗性消退速率甚快，但在田間之抗性極高，可能係氧化解毒酵素之誘發與消退均極爲迅速。使用協力劑測定時發現，氧化解毒酵素爲合成除蟲菊精類殺蟲劑抗藥性之主要機制，使用協力劑可使抗性小菜蛾恢復對除蟲菊精類殺蟲劑之敏感度，數種合成除蟲菊精類在此試驗中之表現均極一致，但仍有少部份之除蟲菊精抗性與氧化解毒酵素無關，是否來自酯酶，則有待進一步之求證。氨基甲酸鹽類殺蟲劑之測定結果發現：加保扶之毒理作用較特殊，與加保利、安丹及納乃得有差別。感性品系小菜蛾之氧化解毒酵素可以解去加保利、安丹及納乃得之毒性作用，然却無法消除合成除蟲菊精之致毒能力，亦無法對加保扶發生解毒作用，可能爲氧化解毒酵素之另一支。小菜蛾亦能對加保扶產生極高之抗藥性，且該抗藥性與其他氨基甲酸鹽類或合成除蟲菊精劑均無交互抗性，但 piperionyl butoxide 可以消除此一抗藥能力。由此判斷，小菜蛾之氧化解毒系統可能分別對（1）合成除蟲菊精類，（2）加保扶及（3）其他三個氨基甲酸鹽類，形成三個獨立的解毒系統，而其間可能不具有交互抗性關係。

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Effects of Different Soil-water-fertilizer Management Practices on Tagged Fertilizer N Uptake by Rice in Amazon Varzea and Sacramento Clay[1]

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Abstract : Using ^{15}N-tagged ammonium sulfate fertilizers as tracers, the uptake of fertilizer N by rice (*Oryza sativa* L.) as influenecd by different soil-water-fertilizer management practices in Amazon varzea soil and Sacramento clay were studied under pot culture conditions. Depending on the practices the recovery of fertilizer N by rice at flowering stage was 60 to 67% in the Amazon varzea soil, while this was 25 to 59% in the Sacramento clay. Those practices which may increase development of aerobic conditions or diffusion of the applied N to the oxidized soil layers greatly reduced the applied N uptake in the Sacramento clay. This was not the case in the Amazon varzea soil. The ammonium-N applied in the Sacramento clay was found to be quickly nitrified under aerobic conditions while this was not so in the Amazon varzea soil. The soil organisms in the two soils immoblized nearly the same amount of fertilizer N (19 to 21%) while only the former soil showed some fertilizer N fixation (2 to 5%) by clay minerals which appeared to contribute some reduction in the recovery of the fertilizer N by rice. It was concluded that marked difference in the tagged N uptake depending on various practices or conditions between the two soils is attributed mainly to the high nitrification and partly to the N fixation by the clay minerals in the Sacramentoclay. Therefore, the practices (deep placement, continous flooding, slowly releasing N fertilizers and nitrification inhibitors) which may minimize the fertilizer N loss through minimizing development of nitrification may not be particularly needed in the Amazon varzea soils having very low nitrification.

Introduction

In the lower Amazon basin of Northern Brazil, there are vast areas of marshland soils (locally called "varzea") and plenty of water resource which can be used for rice production (IRI Research Institute, 1970; IRI Research Institute, 1975; and McIntyre,

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1972). In 1969, a scheme was initiated to develop mechanized rice production in the Amazon basin (IRI Research Institute, 1970; and Wang et al. 1976). Through more than thirteen years research and development, a rice culture technology was developed to produce reasonably good yield (averaging 4.2 to 4.9 tons/ha/crop for 2 crops/year) in a large scale commercial production by continuous planting method (Wang, 1985). When the varzea soils are reclaimed for rice production, the soils in most area have a high level of organic matter (5—8%) and yield 5 to 8 tons/ha of grain with moderate amount (60—30—30 kg/ha) of NPK fertilizer. However, the N requirement increases with number of crops. After 3 to 4 crops, 90 to 120 kg/ha of N is required to produce 5—6 t/ha of grain commercially (IRI Research Institute, 1978; IRI Research Institute, 1981; and Wang, 1985).

Absorption efficiency of applied fertilizer N by rice (*Oryza Sativa* L.) is greatly affected by numerous environmental factors involving soils, climate and soil-water-fertilizer management practices (Broadbent and Mikkelsen, 1968; Cao et al., 1984 a; Cao et al., 1984 b; De Datta, 1981; Miears and Patrick, 1960; Mikkelsen and Finfrock, 1957; and Mitsui, 1956). Information of this on the Amazon varzea soils is extremely limited and needed for establishment of proper N fertilization techniques for rice production in the Amazon basin. In this investigation, using ^{15}N-enriched and ^{15}N-depleted ammonium sulfate fertilizers as tracers, the effects of different soil-water-fertilizer management practices on the uptake of fertilizer N by rice were determined in Amazon varzea soil and Sacramento clay under pot culture conditions. Different practices investigated involved two land preparation (dryland and puddled), several N placements (banded vs mixed and deep vs broadcast), different water managements during the stand establishment, and rate of N application. Sacramento clay, one of the principal rice soils in California (Mikkelsen and Evatt, 1973) and one for which the fate and behavior of N have been well studied, was selected as a standard with which to compare the Amazon soil. ^{15}N tracer techniques had been used previously on Sacramento clay and other California soils (Broadbent and Mikkelsen, 1968; and Manguiat and Broadbent, 1977), and proper N fertilization techniques developed for them (Mikkelsen and Finfrock, 1957; Mikkelsen and Miller, 1968; and Mikkelsen and Evatt, 1973).

Experimental Procedure

Soils--Amazon varzea soil and Sacramento clay were collected, respectively, from a newly reclaimed rice field at Jari Rice Project in the lower Amazon basin of Brazil and a rice field in California. The main properties of the two soils are shown in Table 1. More information on the Amazon varzea soils for rice culture at the Jari Rice Project is presented elsewhere (Wana et al., 1976).

Pot Culture Experiments

Four pot experimets were carried out to determine the effects of different soil-water-fertilizer management practices on the uptakes of fertilizer N and soil N. The first and second experiments were carried out at University of California-Davis while

Table 1. Properties of soils used[a]

Soils	pH	Org. C %	Tot. N %	C. E. C. c mol(+)/kg
Amazon varzea soil	5.1	2.70	.266	22
Sacramento clay.	6.8	1.78	.132	54

[a]. Taxonomic classification :
Sacramento clay: Vertic Haploaquolls   Amazon varzea soil: Tropaquepts
pH. H_2O: soil=1 : 1
Org. C. Wet combustion method
Tot. N. Kjeldahl method
C. E. C. Ammonium acetate method.

the third and forth experiments were carried out at Jari Rice Project, Sao Raimundo, Belem, Para, the Amazon basin, Brazil.

Pot Culture Experiment #1.

Using Sacramento clay the effects of a number of different soil-water-fertilizer management practices on uptakes of the tagged soil fertilizer N and soil N were determined. Before the soils were potted, they were fully air dried and passed through a 5 mm sieve. Two kg lots of the soil were weighed into plastic pots lined with polyethylene bags. Except a few pots in which different rates of N were used, all pots received 400mg N as $(NH_4)_2SO_4$ of either ^{15}N-enriched (4.155 atom% ^{15}N) or ^{15}N-depleted (0.0072 atom % ^{15}N). This would give 200 mg/ka N on air dry soil basis. All pots received enough P and K with KH_2PO_4 (90 mg/kg P and 110 mg/kg K) and 20 mg each of iron and zinc (in chelate materials) at 14 days after seeding. For dryland preparation, N fertilizers were applied in 20 ml of solution by inserting a pipette to a depth of 5cm depth. This was to simulate a band application to achieve a deep placement.

For the puddled soil preparation, the N fertilizer solution was first added on the surface of the puddled soil and then incorporate into a depth of 5 cm by hand using a stainless steel spatula. This was to simulate incorporation of N fertilizer under puddled condition, which was considered to be the most likely method in which deep placement of the fertilizer into the soils could be achieved under the wet and puddled condition.

Different soil-water-fertilizer management practices examined were as follows :

(A). Eight factorial conmbinations of two land preparations (dryland and puddled) and four water managements for stand establishment.

Two land preparations

1). Dryland (Approximately 5 mm and less in particle size)

2). Puddled (Puddling was done mechanically by hand with a steel spatula to a depth of 5 cm depth)

Four water managements for stand establishment

1). Continuous flooding after seedling or zero day drainage (0 DD)

2). Three days drainage after seeding before reflooding (3 DD)

3). Seven days drainage after seeding before reflooding (7 DD)

4). Fourteen days drainage after seeding before reflooding (14 DD)

(B). Two placements (under dryland and 0 DD condition)

1). Broadcast on the surface of soil at 14 days after seeding.

2). Deep placement (banded at a 5 cm depth).

(C). Four rates of nitrogen application (under dryland and 0 DD condition)

1). 0 mg/kg N

2). 100 mg/kg N

3). 200 mg/kg N

4). 400 mg/kg N.

Each treatment was replicated four times in a randomized complete block desigh. The first and second blocks were applied with ^{15}N-enriched fertilizer and second and fourth blocks with ^{15}N-depleted fertilizer. Immediately after application of nitrogen fertilizer the pots were flooded with water to a depth of 5 cm. One day after the pots were flooded, 10 pregerminated rice seeds (*Oryza sativa* L. var. "Earlirose") were placed in each pot. For those treatments which required drainage (3 DD, 7 DD and 14 DD), water was drained by siphoning one day after seeding. Seven to 10 days after seeding each pot was thinned to 5 seedlings. Hand weeding was used to control the weeds. One day after flowering (66 days after seeding), the plants were cut off as near the soil surface as possible for the dry matter yield and N uptake (untagged and tagged N) determination. For several treatments, the root growth and N-uptake by roots were also determined to determine the balance sheet of tagged N in plant-soil system.

Pot Culture Experiments #2

In this pot experiment, the effects of land preparations (dryland and puddled) and two N placements (banded and mixed) were determined for the Amazon varzea soil and Sacramento clay. In pot experiment #1, it was not possible to distinguish the effect of the land preparation from that of placement, and this was made possible in pot culture #2. Due to a limited amount of Amazon varzea soil available, small pots (.25kg. of soil per each pot) were used. The same method as that used for the experiment #1 was to grow Earlirose rice. All pots received 200 mg/kg N (air dry soil basis) of ^{15}N-enriched ammonium sulfate fertilizer. The treatments involved:

1). Dryland preparation with the N fertilizer banded at a 3 cm depth (Dry-Banded)

2). Dryland preparation with the N fertilizer mixed thoroughly with soil up to a depth of 3 cm (Dry-Mixed)

3). Puddled with the N fertilizer banded at a 3 cm depth (Puddled-Banded)

4). Puddled with the N-fertilizer mixed thoroughly with soil up to a depth of 3 cm (Puddled-Mixed).

The treatment of 3)-Puddled-Mixed was not carried out for the Amazon varzea soil because the soil was not enough. Each treatment was replicated two times in a randomized complete block design. All pots were kept flooded continouously until heading. One day after heading (61 DAS), the top was cut for the yield and N uptake determination. Roots were also separated from the soils for determination of the balance sheet of the tagged N in the soil-plant system.

Pot Culture Experiment #3

This experiment was conducted at Jari Rice Project in Brazil to determine the effects of placements (deep placement and broadcast) and prolonged draining (14 DD) after seeding on the uptake of tagged N in the Amazon varzea soil. The soil was prepared under dryland condition. ^{15}N-enriched ammonium sulfate fertilizer was used as a tracer. The treatments investigated were :

1). N fertilizer banded at a 5 cm depth below the soil surface and kept flooded continuously (0 DD)
2). N fertilizer banded at a depth of 5 cm and kept for fourteen days drainage after seeding then reflooded (14 D D)
3). N fertilizer broadcasted on the soil surface at 14 days after seeding and kept flooded continuously (0 DD).

All pots (3 kg soils per each pot) received 200 mg/kg N on soil basis. IR 22 rice variety (*Oryza sativa* L.) was used as an indicator. Each treatment was replicated three times in a randomized complete block. The plants were cut one day after heading (80 DAS) for the dry matter yield and the N uptake determination.

Pot Culture Experiment #4

Using ^{15}N-depleted ammonium fertilizer as a tracer, the fertilizer N uptake efficiency as influenced by 4 rates of N application (0, 100, 200 and 300 mg/kg) was determined for the Amazon varzea soil at Jari Rice Rice Project, Brazil. The same method and rice variety (IR 22) used in pot experiment #3 were used. The plants at heading (B8 DAS) were cut for the dry matter yield and the N uptake determination.

Analytical Methods

The plant and soil samples were analyzed for total Kjeldhal N and the tagged N contents (Bremmer, 1965 a and Bremmer, 1965 b). A massspectrometer with a capacity of a precision of .001 atom $\%^{15}N$ was used to analyze the tagged N.

The transformation of ammonium sulfate in soils was determined as follows: Ten (10) mg N as ammonium sulfate dissolved in 1 ml solution was added to 50 gm of air-dried soils in an Erlenmeyer flask, and sufficient water was added to bring to the field capacity moisture content. This gave 200 mg/kg N on soil basis. The flask was stopped with a solid stopper with a small hole in the center of the stopper and incubated at the room temperature (25°C). At varying intervals ammonium was extracted with 150 ml solution containing 1 N NaCl-0.1 N HCl. The soil extract was made to 200 ml with water. Ammonium-N was determined by distillation with MgO. After the ammonium-N was distilled over, the receiver was changed, and Devardas alloy and additional water were added to the distillation flask. The nitrate plus nitrite was determined by a second distillation.

Clay-fixed ammonium in soils was analyzed by using the method of Dhaiwal and Stevenson (1958). Organic N in soils was determined by getting the difference between the values of total N and clay-fixed ammonium.

Rerults and Discussions

Effects of Different Soil-Water-Fertilizer Practices Tagged Fertilizer N Uptake.

Effects of different soil-water-fertilization practices on tagged N uptake are given in Table 2. The practices involved land preparations (dryland vs puddled), placements (banded vs mixed and deep placement vs broadcast), water managements during stand establishment (0 DD, 3 DD, 7 DD and 14 DD) and different rates of N application (100 to 400 mg/kg). It was interesting to find that the uptake of tagged N in the Sacramento clay was greatly affected by different land preparations, placements, and water magements, while this was not the case in the Amazon varzea soils.

In the Sacramento clay puddled reduced the N uptake and this was especially ob-

Table 2. Effect of various soil-water-fertilization management practices on tagged fertilizer N uptake in Amazon varzea soil and Sacramento clay

Treatment	Source of pot expt.	Tagged fertilizer N uptake			
		Amazon varzea soil		Sacramento clay	
		mg/kg	%	mg/kg	%
Land preparation					
Dry (N banded)	#1			205	51.3
Puddled (N mixed)	#1			121	30.3
$LSD_{.05}$				20	5
CV (%)				12.3	12.3
Dry	#2	125.6	62.8	64.4	32.2
Puddled	#2	126.4	63.2	53.4	26.7
$LSD_{.05}$		N S	N S	N S	N S
CV (%)		8.3	8.3	8.3	8.3
N placement					
Banded	#2	118.8	59.4	70.2	35.1
Mixed	#2	129.2	64.6	49.4	24.7
$LSD_{.05}$		N S	N S	10.4	5.2
CV (%)		8.3	8.3	8.3	8.3
Deep placement	#3& #1(1)	132	66	105	52.5
Broadcast	#3& #1(1)	128.3	64.2	87	43.5
$LSD_{.05}$		N S	N S	10.5	5.3
CV (%)		6.4	6.4	9.1	9.1
Water management					
0 DD	#3& #1(1)	132.0	66.0	112.5	56.3
3 DD	#1			106.0	53.0
7 DD	#1			105.0	52.5
14 DD	#3& #1(1)	137.3	68.7	86.5	38.3
$LSD_{.05}$		N S	N S	10.5	5.3
CV (%)		6.4	6.4	9.1	9.1
Fertilizer N rate			65.9		
100 mg/kg	#4& #1(2)	65.9	66.0	48.2	48.2
200 mg/kg	#4& #1(2)	132.0	66.5	106.2	53.1
300 mg/kg	#4	198.0			
400 mg/kg	#1			237.2	59.3
$LSD_{.05}$		34.5		16.4	
CV (%)		10.7		10.5	

(1) #3 and #1 for Amazon varzea soil and Sacramento clay, respectively.

(2) #4 and #1 for Amazon varzea soil and Sacramento clay, respectively.

vious when the N was mixed (incorporated) into the soil under puddled condition as compared with that under dryland-banded. When the N was banded at a depth of 5 cm under dryland condition the N uptake efficiency was 51.3%, and this was greatly reduced to 30.3% under the puddled-mixed condition. In pot experiment ♯2 in which the average N uptake efficiency through the two N application methods (mixed and banded) was found to be 27.6% under puddled condition, while this under dryland preparation was increased to 35.2% though not significant at 5%.

In pot experiment ♯2, the tagged N uptake efficiency in the Sacramento clay was 24.6% when the N was incorporated into the top layer of a 3 cm depth, while this was greatly increased to 35.2% when the N was banded at 3 cm below the soil surface. In experiment ♯1, the tagged N uptake efficiency was 43.5% when the N was broadcasted on the soil surface while this was increased to 52.5% when the N was banded at 5 cm below the soil surface.

In the Sacramento clay the tagged N uptake efficiency was greatly reduced (38.3%) when the soil in which N was banded at 5 cm below the soil surface was drained for 14 days during the stand establishment. When the soil was drained for a period not more 3 to 7 days, the N uptake efficiecy was slightly reduced to 53% from that (56.3%) found in the continuous floodiog (0 DD), however, the reduction was not significant statistically.

It was very interesting to note that all of the practices (puddled, mixed, broadcaste and 14 DD) which reduced the tagged N uptake efficiency in the Sacramento clay did not affect the N uptake efficiency in the Amazon varzea soil. On the contrary, most of them (puddled, mixed and 14 DD) even slightly increased the N uptake efficiendy though the increase was not significant statistrally.

It was also found that the N uptake efficiencies in the Amazon varzea soil was obviously and consistently higher (59 to 67%) than that in the Sacramento clay (25 to 59%) under all the conditions investigated. The amount of the N uptake increased linearly with the amount applied in both of the soils (Fig. 1). However, in the Sacramento clay the efficiency of uptake increased with the rate, and for this reason, the N uptake was found to be a negative value at 0 rate of N when it was determined by a linear regression equation.

The marked reduction in the N uptake found in the Sacramento clay but not in the Amazon varzea soil due to different practices (puddled, mixed, broadcast and prolonged drainage) seems to be due to the difference in the rate of nitrification found between the two soils. In Fig. 2 the transformation of ammonium-N in the two soils under aerobic condition is illustrated and indicates that virtually no nitrification of the added ammonium-N took place over 14 days incubation in the Amazon soil, while nearly all of the added ammonium-N was nitrified in the Sacramento clay in the same period. After flooding rice soils differentiate into two layers, the top oxidized layer (.5 to 1cm) and the reduced layer below (Mitsui, 1956 and Ponnamperma, 1972). Ammonium form of N fertilizers in the oxidized layer is stable and not oxidized. And the nitrate formed from the added ammonium-N in the oxidized layer may be lost subsequently through

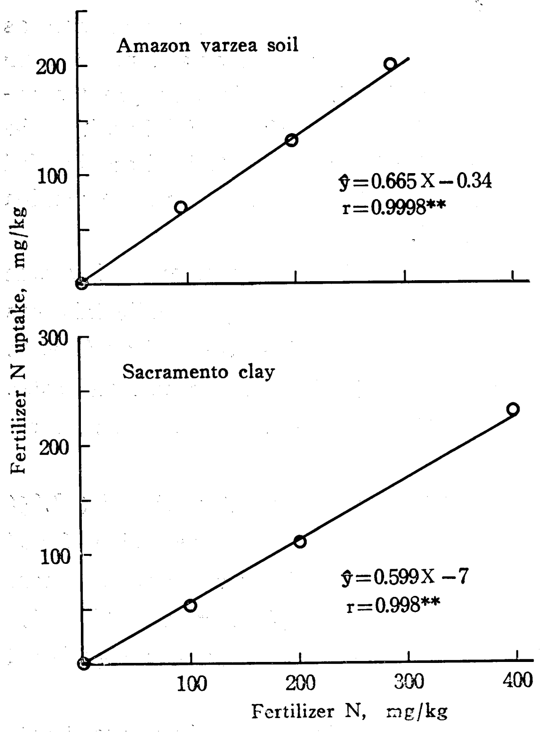

Fig. 1. Relation between fertilizer nitrogen uptake by rice and level of nitrgen applied in two soils.

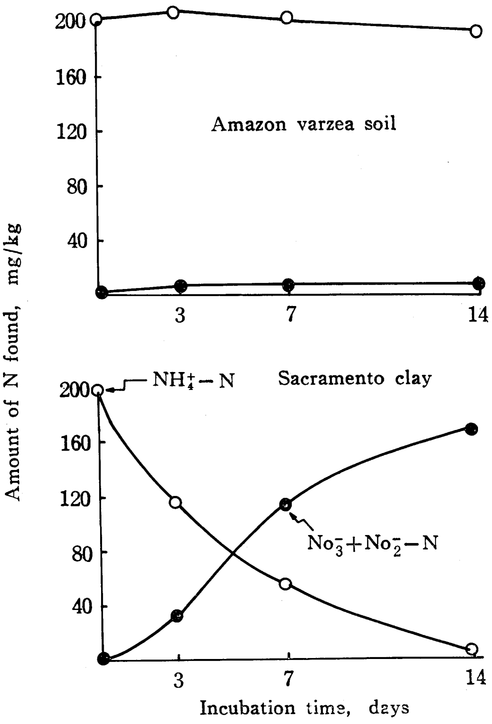

Fig. 2. Transformation over time of ammonium sulfate N (200mg-kg) in Amazon varzea soil and Sacramento clay under aerobic condition.

leaching or denitrification in the interlayers between the oxidized and reduced (Mitsui, 1956 and Ponnamperma, 1972).

When the ammonium-N was broadcasted on the surface of the Sacramento clay, the N was presumably nitrified quickly and then could be lost through denitrification. Since the nitrification rate in the Amazon varzea soil was very low, it is not unreasonably to expect that the broadcast did not reduce the N uptake in the Amazon varzea soil. In pot experiment #2 the N could diffuse to the oxidized layer more quickly wheh the N was mixed in the top 3 cm layer than when the N was banded at 3 cm below the soil surface. Therefore, the mixed application in the Sacramento clay substantially reduced the N uptake as compared with the banded application. However, the mixed application presumably reduce the N uptake in the Amazon varzea soil. On the contary, the mixed application apparently increased the interception of the N by the rice roots resulting in a small increase of the N uptake.

When the soils were drained after seeding, an aerobic condition might have developed in the soils depending on the length of draining. Under the pot culture condition, for the Sacramento clay a sufficient aerobic condition was presumably developed when the soil was drained for 14 days, and the N uptake of this treatment was substantially reduced. However, the same practice did not reduce the N uptake in the Amazon varzea soil. Again this can be explained by the slow nitrification in the soil.

The finding that the puddled especially puddled-mixed practice reduced the N uptake in the Sacramento clay as compared with that for the dry-banded practice was also due to the quick nitrification in the soil. When the N was mixed into the soil under puddled condition, it could diffuse to the oxidized soil layer and rhizosphere more quickly than the condition in which the N was banded in the deep soil, resulting in a significant reduction of the N uptake. The finding that a significant reduction in the N uptake by this practice in the Sacramento clay but no in Amazon varzea soil suggested that the loss was mainly through nitrification-denitrication, though the loss though volatilization of ammonium-N cannot be excluded. A recent report (Smith and DeLaune, 1984) indicated that the nitrification-denitrification occurs in the rice rhizosphere evidenced by NO_2+N_2 measurement in laboratory. The N loss due to the rhizosphere effect was found to as much as 13% of the total N (Reddy and Patrick, 1986). The refore, any practices which may increase the chance of the applied N to reach the rhizosphere can increase the N to the lost through nitrification-denitrifiction and also absorbed by the roots. If the soils have very low nitrification such as the Amazon varzea soil, the N uptake is supposed be increased.

In California and many other major rice growing areas, to increase the efficiency of the ammonium N fertilizer for rice, the practices which may reduce the loss due to nitrification-denitrification such as deep and band placement (Broadbent and Mikkeslen, 1968; Cao et al., 1984 a; Cao et al., 1984 b; and Mitsui, 1956), continuous flooding (Mitsui, 1956 and Ponnamperma, 1972), use of nitrification inhibitors (De Datta, 1981; Prasad and De Datta, 1979; and Wells, 1977) and use of slowly releasing fertilizer (De Datta, 1981; and Prasad and De Datta, 1979) have recommended. This, however, may not be particularly needed in the Amazon varzea soils having very low nitrification, In fact, in the rice culture (direct seed and mechanized production) developed in the Amazon regions-Surinam, Guyana and Jari Rice Project in Brazil (where the author had worked for more than 13 years between 1972 and 1986), a subsurface basal dress of the N is not practiced. If the finding of this report is found to be generally true in all the Amazon varzea soils, such practice is well justified.

Recovery of Soil N and Fertilizer N by Rice Under Different Conditions

Table 3 gives the recoveries of soil N and fertilizer N (tagged) by the rice in the two soils under different pot sizes. It is seen that the recovery of soil N as well as the tagged fertilizer N in the Sacramento clay varied greatly with the different conditions while this was not the case in the Amazon soil. In the Sacramento clay the recoveries of both soil N and the tagged N reduced significantly when the pot size was reduced to .25kg soil per pot. When the pot size 2 kg soil per pot the recoveries of the tagged N and the soil N were 53 and 4.73%, respectively, and these dropped to 29.9 and 2.49%, respectively, when the pot size was reduced to .25kg per pot. The balance sheet analysis of the tagged N indicated that the N not accounted for (lost through denitrification presumabley) under the bigger pot size was 5.5%, but this increased dramatically to 29.5% under the smaller sizepot. In the Amazon varzea soil the change in pot size hardly affected the recoveries of both the soil N and the tagged N. The tagged N lost in the smaller size pot (.25kg per pot) was 4%, and though the tagged N lost in

Table 3. Recoveries of soil N and tagged fertilizer N by Earlirose rice in two soils as affected by size of soil volume in pot in Amazon varzea soil and Sacramento clay

Experiment sources	Amazon varzea soil		Sacramento clay	
	Expt. #2	Expt. #3	Expt. #2	Expt. #1
Pot size kg/pot	25	3	.25	2
F. N applied mg/kg	200	200	200	200
F. N uptake mg/kg	126	132	60	106
%	63	66	29.9	53
F. N lost %	4	ND	29.5	5
Total soil N mg/kg	2,660	2,660	1,320	1,320
Soil N uptake mg/kg	117	112	32.8	62.5
%	4.4	4.2	2.49	4.73

F. N Tagged fertilizer N.

the bigger pot (3 kg per pot) was not determined, the nearly same tagged N recoveries found in the two pot sizes suggested the N lost in the bigger pot would not be different greatly from 4%.

Again the difference in the nitrification in the two soils may explain the marked difference found for the recoveries between the two soils. The mineralized soil N and the tagged N in the soils could reach the oxidized layer more quickly under the smaller size pot than under the bigger size pot. Therefore, more N would be lost through nitrification-denitrification in the smaller size pot for the Sacramento clay having quick nitrification. While for the Amazon soil the pot sizes would hardly affect the N recoveries because of low nitrification.

Balance Sheet of Fertilizer N as Influenced by Different Management Practices

Table 4 gives the balance sheet for the recoveries of the tagged N in the soil-plant system in the Sacramento clay as affected by different practices of land preparations (dryland and puddled), N applications (banded and mixed) and water managements (0 DD and 14 DD) in pot experiment #1 in which the pot size was 2 kg soil per pot. It is seen from Table 4 that the rice shoots, roots, soil organic matter and clay minerals, respectivey, recovered 25 to 53, 7.5 to 16, 22 to 27 and 1.5 to 5% of the tagged N depending on different practices. The total recoveries were 63 to 95% while the tagged N not unaccounted for (lost) were 5.5 to 37% depending on the practices. Under the condition of dryland-banded, the tagged N lost was 5.5% and this increased sharply to 25% under the condition of puddled-mixed. Draining for 14 days increased the tagged N loss by approximately 14% over that of continuous flooding (0 DD). The puddled-mixed practice slightly increased the fixation of the tagged N by clay minerals and the immobilization by soil organic matter.

The puddled-mixed practice apparently increased the chance of applied N to diffuse

Table 4. Balance sheet of tagged N in Sacramento clay by different soil-water-fertilization management practices (pot culture experiment #1, 2 kg air dry soil per pot, and 400 mg N per pot added)

Treatment	Tagged		fertilize N		recovery	
	Shoot %	Root Soil %	Orgagic %	Clay-fixed %	Total %	Lost %
Dry-banded-0 DD	53.0	16.0	23.5	2.0	94.5(±6.4)	5.5
Dry-banded-14 DD	43.5	15.0	22.0	1.5	82.0(±6.4)	18
Pudd.-mixed-0 DD	37.5	10.5	27.0	5.0	75.0(±9.9)	25
Pudd.-mixed-14 DD	24.5	7.5	26.0	5.0	63.0(±6.4)	37

Lost Those not accounted for are supposed to be lost.
Figures in the parenthes are the standard errors.

to the rhizosphere as well as the oxidized soil layer where nitrification-denitrification could could take place resulting in 20% more loss of the fertilizer N. Puddled-mixed could also increase the chance of the fertilizer N to be intercepted by the aerobic soil microorganisms in the rhizosphere and oxidized soil layer resulting in 4% higher N immobilization than dryland-banded. The puddled-mixed was also supposed to increase the contact of applied N with clay minerals resulting in 3% higher fixation. Therefore, substantially lower recovery of the fertilizer N by the rice under puddled-mixed condition than under dryland-banded was due mainly to the greater loss through denitrification and partly to the increased fixation by the clay minerals and immobilization by the soil organisms. Fixation of N by clay minerals may retard the absorption by rice. However, recent literature suggests that the clay-fixed N is readily released and absorbed by rice (Keerthinsingle at al., 1984 and Keerthinsingle at al., 1985). Therefore, in the long run N-fixation by clay minerals is beneficial for the N conservation.

Table 5 gives the balance sheet of for the recoveries of the tagged N in the soil-plant system in the two soils as affected by different land preparations and placements in pot experiment #2 in which smaller size of pot (.25kg per pot) was used. It is seen that in the Sacramento clay the total recovery of the tagged N was 57 to 69% and this in the Amazon soil ranged from 95 to 97%. The N recovered by the rice shoot in the Sacramento clay was 25 to 36% and this in the Amazon soil was 60 to 66%.

In pot experiment #1 the fertilizer N was banded at a depth of 5cm while this, in pot experiment #2, was a depth of 3 cm. This, in the Sacramento clay, apparently enabled the banded N to diffuse the oxidized soil layer more quickly in the #2 experiment resulting in a substantially greater loss of the N. It was found that puddled and mixed increased the N loss, respectively, by 2—5 and 10% indicating the mixed was significantly more effective in reducing fertilizer N recovery than the puddled.

Under the condition more conducive to nitrification and denitrification in pot experiment #2, 35 to 43% of the fertilizer N was lost from the soil-plant system in Sacramento clay. And this in the Amazon varzea soil was substantially lower only 3 to 7% For this, the recovery of fertilizer N by the rice (shoots and roots) in the Amazon

Table 5. Balance sheet of tagged N in two soils as affected by different soil-water-fertilization management practices (pot culture experiment #2, .25 kg air dry soil per pot, and 50 mg N per pot added)

Treatment	Shoot %	Root %	Soil organic %	Clay-fixed %	Total %	Lost %
			Sacramento clay			
Dryland	32.1	9.0	20.3	3.5	64.9(±11.7)	35.1
Puddled	26.7	8.8	20.8	3.5	59.8(±9.1)	40.2
Banded	35.1	11.3	20.5	2.0	68.9(±10.7)	31.1
Mixed	24.7	6.5	20.5	5.0	56.7(±11.7)	43.3
			Amazon varzea soil			
Dryland	62.8	12.5	21.8	trace	97.1(±0.7)	2.9
Puddled	63.3	11.5	18.5	trace	93.3(±10.0)	6.7
Banded	59.4	13.0	21.5	trace	93.9(±9.2)	6.1
Mixed	64.6	11.8	20.5	trace	96.9(±3.9)	3.1

Lost, Those not accounted for are supposed to be lost.
Figures in the parenthes are the standard errors.

varzea soil (73 to 76%) was approximately twice of that in Sacramento clay (31 to 47%).

The soil organisms in the Amazon varzea soil immobilized nearly the same amount of fertilizer N as those in Sacramento clay. The clay minerals in Sacramento clay fixed 2 to 5% of fertilizer N depending on the treatments, while the clay minerals in the Amazon varzea soils showed little N fixation. In the Amazon soil where virtually neither nitrification nor fixation of N by clay minerals took place, puddled-mixed increased the recovery of fertilizer N presumably because the puddle and mixed increased the diffusion of N in the soil so that interception by root surface was increased.

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利用N^{15}標識酸硫銨探討不同土壤—水分—肥料管理方式對水稻氮吸收的影響

王 接 皇

摘 要

本研究使用N^{15}標識硫酸銨，以盆栽試驗探討巴西亞馬遜河下游沼澤土和美國沙加緬度粘土，在不同土壤—水分—肥料管理下，所施氮肥被水稻吸收利用情形。

試驗結果顯示，亞馬遜沼澤土與沙加緬度粘土水稻在開花期之氮肥回收率分別爲60～67％及25～59％；後者依不同的土壤管辦而有很大差異。會導致土壤好氣狀態之發展或導致所施氮肥往氧化層擴散之各種土壤管理均沙使加緬度粘土之肥料回收率降低，而亞馬遜沼澤土則無此現象；前者土壤中所施銨態氮肥在好氣狀態下迅速硝酸化，而後者則否。所施肥料氮素被土壤微生物固定之量在兩種土壤差異不大（19～21％），只是沙加緬度粘土之粘土礦物略有固氮能力（２～５％）而已。故兩種土壤隨者土壤管理差異所致氮肥收率之差異主要係因沙加緬度土壤之硝化作用較盛，易導致脫氮損失所致。

爲防止水田硝化作用，吾人常利用氮肥深肥，持續淹水，施用緩效性氮肥或硝化抑制度等處理，但在本試驗之亞馬遜沼澤土，因硝化作用進行極爲緩慢，故上述各處理似非必要。

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